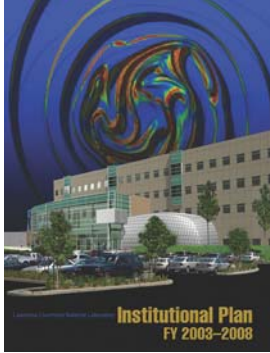


Lawrence Livermore National Laboratory

Institutional Plan

FY 2003–2008



About the cover

At Lawrence Livermore National Laboratory, we just celebrated our 50th year of operation. One continuing theme throughout our history is national leadership in furthering the development and use of high-end computers for scientific applications. This Institutional Plan's cover and divider pages are highlighted with recent images of work using our supercomputing tools and expertise. The cover shows a rendering of the Terascale Simulation Facility, which began construction in April 2002. It will house the ASCI Purple 100-teraops supercomputer for the Advanced Simulation and Computing (ASCI) Program. Calculations for the background image of turbulent mixing were performed on the ASCI White supercomputer at Livermore.

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Institutional Plan

FY 2003–2008

Lawrence Livermore
National Laboratory

Department of Energy
National Nuclear Security Administration
University of California

October 2002
UCAR-10076-21

Navigating the Institutional Plan

This year, the Institutional Plan is divided into the following sections:

Section 1. Laboratory Overview

Livermore's mission, roles, and responsibilities as a Department of Energy/National Nuclear Security Administration (DOE/NNSA) national laboratory and the foundation for decisions about the Laboratory's programs and operations.

Section 2. Laboratory Science and Technology—National Security

A description of the situations, issues, and planned thrusts of Livermore's national security programs: stockpile stewardship, countering the proliferation and use of weapons of mass destruction, homeland security, and other defense-related activities.

Section 3. Laboratory Science and Technology—Enduring National Needs

A description of the situations, issues, and planned thrusts of Livermore's programs to meet enduring national needs—in energy, earth and environmental sciences, bioscience and biotechnology, and fundamental science and applied technology, including Laboratory Directed Research and Development. The Laboratory's partnerships and collaborations with industry and academic institutions are also described.

Section 4. Laboratory Operations

Facilities and human resources information, including Laboratory staff composition and diversity and status of facilities with links to Contract 48 management and to Livermore's Comprehensive Site Plan.

Section 5. Appendices

- Program resource requirement projections: resource data for FY 2003–2008.
- Livermore organization chart.
- References for this 2003–2008 Institutional Plan.

Institutional Plan FY 2003–2008

Department of Energy/National Nuclear Security Administration

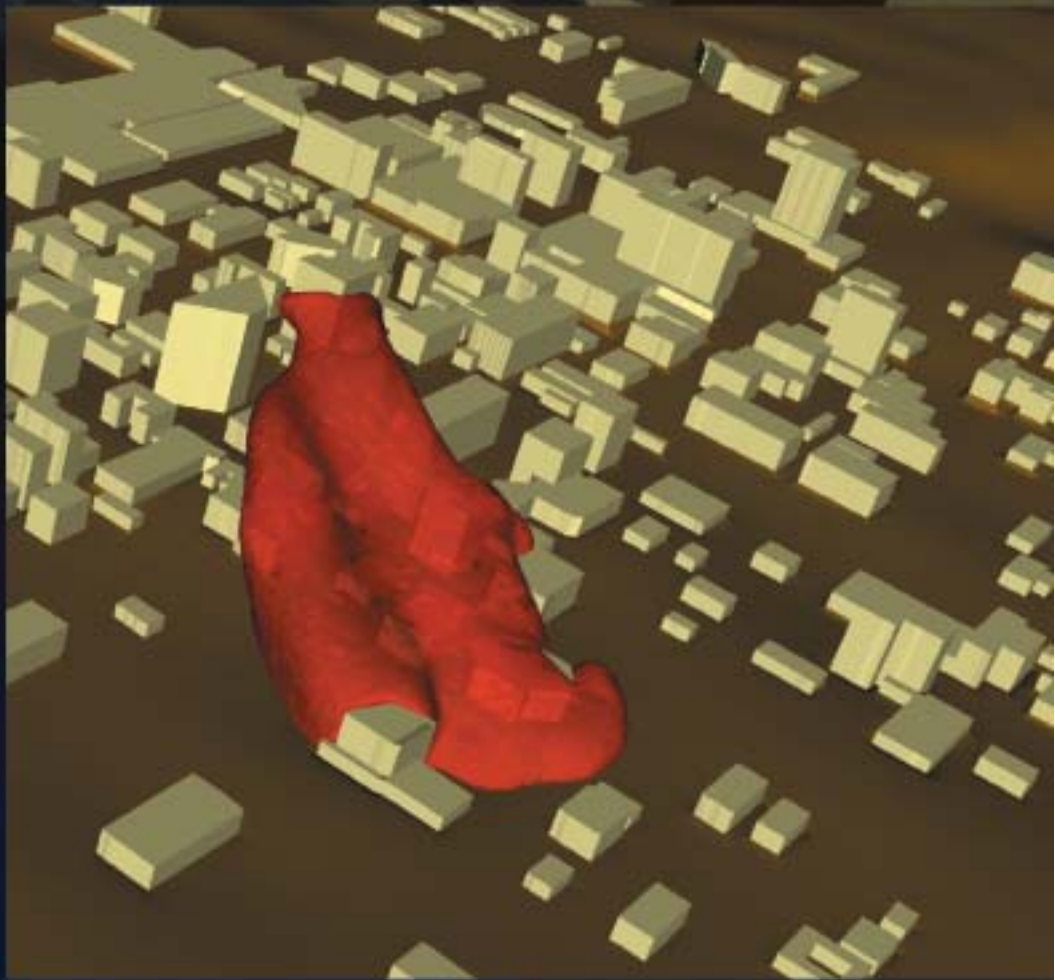
Lawrence Livermore National Laboratory

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DIRECTOR'S STATEMENT

Institutional Plan FY 2003–2008



A simulation of atmospheric release in a city is performed by Livermore's National Atmospheric Release Advisory Center (NARAC). NARAC is a national emergency response service for real-time assessment of incidents involving the release of nuclear, chemical, biological, or natural hazardous materials. Through the Local Integration of NARAC with Cities (LINC) effort, we are working to better integrate these capabilities with local emergency management and response centers for homeland security.

DIRECTOR'S STATEMENT

Institutional Plan FY 2003–2008

THESE are exciting times for Livermore—full of challenges and opportunities—as you will glean from the Lawrence Livermore National Laboratory's Institutional Plan 2003–2008. We just celebrated our golden anniversary in 2002. As the new Laboratory Director, I used the occasion to reflect on Livermore's strengths, priorities, and values as we start our next 50 years of service to the nation. We are poised to take on the challenges; we must seize the opportunities.

Challenges arise from the Laboratory's national security mission to sustain a safe and effective nuclear deterrent, counter the proliferation of weapons of mass destruction, and strengthen homeland security. As we advance science and technology to meet important mission objectives, we also must meet high standards in business practices and carry out operations safely, securely, and in an environmentally responsible manner. Laboratory management and the actions of all employees are accountable to the American public, which trusts us with vital responsibilities and holds high expectations for our performance.

Opportunities are created by the Laboratory's outstanding workforce, which is committed to solving today's pressing national problems and anticipating tomorrow's. The exceptional capabilities and facilities at Livermore enable researchers to expand the frontiers of science and technology.

Stockpile Stewardship. Challenges and opportunities abound in our efforts to ensure that the U.S. nuclear weapons stockpile meets the nation's needs well into the 21st century. As a National Nuclear Security Administration (NNSA) laboratory, we are a key contributor to the Stockpile Stewardship Program. A wide range of activities at Livermore supports annual assessments of the continued safety, reliability, and



Michael R. Anastasio
Director

performance of stockpiled nuclear weapons. We are also working to improve the methodology used in the Annual Certification Process. In addition, we are committed to meeting major milestones to extend the lifetime of weapons and improve the scientific capabilities that provide the foundation of stockpile stewardship.

New capabilities being acquired for stockpile stewardship will give Laboratory researchers unprecedented opportunities for scientific discovery. NNSA's Advanced Simulation and Computing (ASCI) Program brought the 12-teraops (trillion operations per second) ASCI White to Livermore. The supercomputer is being shared by the three NNSA laboratories to conduct high-fidelity three-dimensional simulations of weapons physics. ASCI White and the Laboratory's unclassified terascale computing capabilities will soon be augmented with the 100-teraops ASCI Purple machine and a second supercomputer, a research machine called Blue Gene/L. Contracts with IBM to build these machines were awarded in 2002. The 253,000-square-foot Terascale Simulation Facility is under construction; it will provide space for the very large ASCI Purple system and associated capabilities needed to manage and visualize the incredible amount of data that will be generated.

We also will soon begin performing experiments in the National Ignition Facility (NIF), a cornerstone of the Stockpile Stewardship Program. In

December 2002, the NIF project achieved "early light," when more than 40 kilojoules of infrared laser light were generated in the first four of the NIF's 192 laser beams. This important milestone demonstrates performance of lasers that will be replicated to complete the entire system. Our next milestone, which we set the goal of achieving in March 2003, is to transport the four laser beams into the target chamber. NIF is making the transition from cutting-edge construction project to unparalleled experimental facility. Using NIF, scientists will better understand nuclear weapon performance, achieve nuclear fusion ignition and energy gain, and advance basic science in areas such as astrophysics and materials science. We have set a goal of performing 1,500 experiments using NIF before the facility officially opens with all 192 beams operational in 2008.

Nonproliferation and Homeland Security.

The events of September 11, 2001, lent new urgency to the Laboratory's efforts to apply its technologies, tools, and expertise to stem the proliferation of weapons of mass destruction and better prepare the nation against terrorist use of such weapons. Prior to the attacks, Livermore researchers recognized the threat of terrorism and identified technical opportunities to develop vastly improved instruments for detecting and identifying biological weapons agents that would be field-portable. Subsequent efforts led to our development of miniaturized DNA analysis technologies that are now at the core of the nation's biodefense capabilities.

More generally, because we had been addressing the threat long before September 11, we were able to respond immediately and broadly to the challenge of homeland security after the attacks. The Laboratory has exceptional capabilities and active programs addressing nuclear, radiological,

biological, and chemical threats. We take a comprehensive, end-to-end approach to the problem and work closely with federal, state, and local response agencies to develop technologies and systems that meet real-world operational needs.

The newly created Department of Homeland Security presents us the opportunity and responsibility to expand applications of our outstanding science and technology to counter the threat posed by potential terrorist use of weapons of mass destruction against the United States. In December 2002, I formed a Homeland Security Organization at the Laboratory in order to build a long-term, substantial relationship in support of the new Department.

Meeting Broader National Needs.

The Laboratory is able to respond to a broad range of vital national needs because of our special capabilities and our multidisciplinary approach to problem solving. For example, Livermore's scientific computing resources offer the potential of unprecedented levels of understanding in climate modeling, environmental management, materials science, fusion energy, molecular biology, and astrophysics. These and other research interests align with the enduring missions of the Department of Energy (DOE), and we pursue projects that reinforce our national security work.

Science and Technology Investments.

NIF and ASCI Purple are major investments in research capabilities at Livermore, but they are not the whole story about our commitment to scientific excellence. We have launched an in-depth review of our current science and technology investment strategy. We will update it, particularly in light of the evolving needs of the Stockpile Stewardship Program, the imminent

beginning of the NIF science program, rapid expansion of our supercomputing capabilities, and the Laboratory's role in the Department of Homeland Security. The new science and technology strategy will shape our investments in FY 2003 and beyond. Great strides in science underpin our continued outstanding service in the national interest and make the Laboratory an exciting place for young scientists and engineers to grow their careers.

An Exceptional Workforce. An outstanding workforce at Livermore—having an important mission and equipped with exceptional facilities—creates opportunities for breakthrough advances in science and technology. Employees are the heart and soul of the Laboratory. We must maintain the caliber of workforce that has allowed Livermore to deliver on its many commitments over the years. The quality of our scientific and technical staff is exemplified in 2002 by the receipt of E.O. Lawrence awards by two Laboratory scientists and six R&D 100 awards, the most by any national laboratory, by Livermore research teams.

I have set a high priority on ensuring the continuing vitality of the workforce. We need to be thoughtful and strategic in how we recruit and retain the best talent available so that the Laboratory has the personnel to meet current and evolving programmatic commitments. Concurrently, we are taking steps to foster the development of the next generation of leaders at all levels. Moreover, the Laboratory must be managed in a way that our employees are empowered to fulfill their full potential, and we must achieve our objectives with regard to workforce diversity.

Laboratory Operations. We are committed to excellence in Laboratory

operations. The dedicated effort of all employees contributes to the Laboratory's efficient business practices, well-run facilities and infrastructure, and safe, environmentally compliant, and secure operations at Livermore. In particular, DOE's Integrated Safety Management System is in place, and we are working with NNSA and the University of California (UC) to implement an Integrated Safeguards and Security Management System. Those systems plus expanded security measures since September 11, 2001, are key efforts to ensure that great science and security can continue working together to carry out the Laboratory's mission.

Over the past decade, the Laboratory has markedly improved operations by using performance-based management as a vehicle for benchmarking against others, providing better services and support, and lowering costs. The strong working partnership we have with NNSA and the University of California—which manages Berkeley, Livermore, and Los Alamos national laboratories—has led to these improvements. We continually work with UC and NNSA to strengthen management. In turn, the Laboratory greatly benefits from the association with the University, which helps to ensure scientific and technical excellence, and strong ties to many UC campuses.

Institutional Values. What the Laboratory does is important—so is how we do it. Individually and collectively, we are accountable for all our actions to fulfill Livermore's missions and responsibilities. The way we operate is a product of our culture and shared values. My senior management team and I recently reflected on our values and stated them clearly and succinctly. These values, which are listed, guide employee's actions and public expectations about our performance.

The Institutional Plan. As a goal-oriented Laboratory, we have a “passion for mission,” which leads our list of values. This Institutional Plan describes our strategic direction and our current programmatic accomplishments. Livermore’s activities during this institutional planning period, which are carried out with a wide range of research partners, will help NNSA, DOE, the Department of Homeland Security, and other agencies to achieve success in their missions. These efforts set the course for the Laboratory in the first decade of the 21st century.

With our commitment to national service and excellence in all our activities, we have an exciting future with much to accomplish to make the world more secure and a better place to live.

We Value

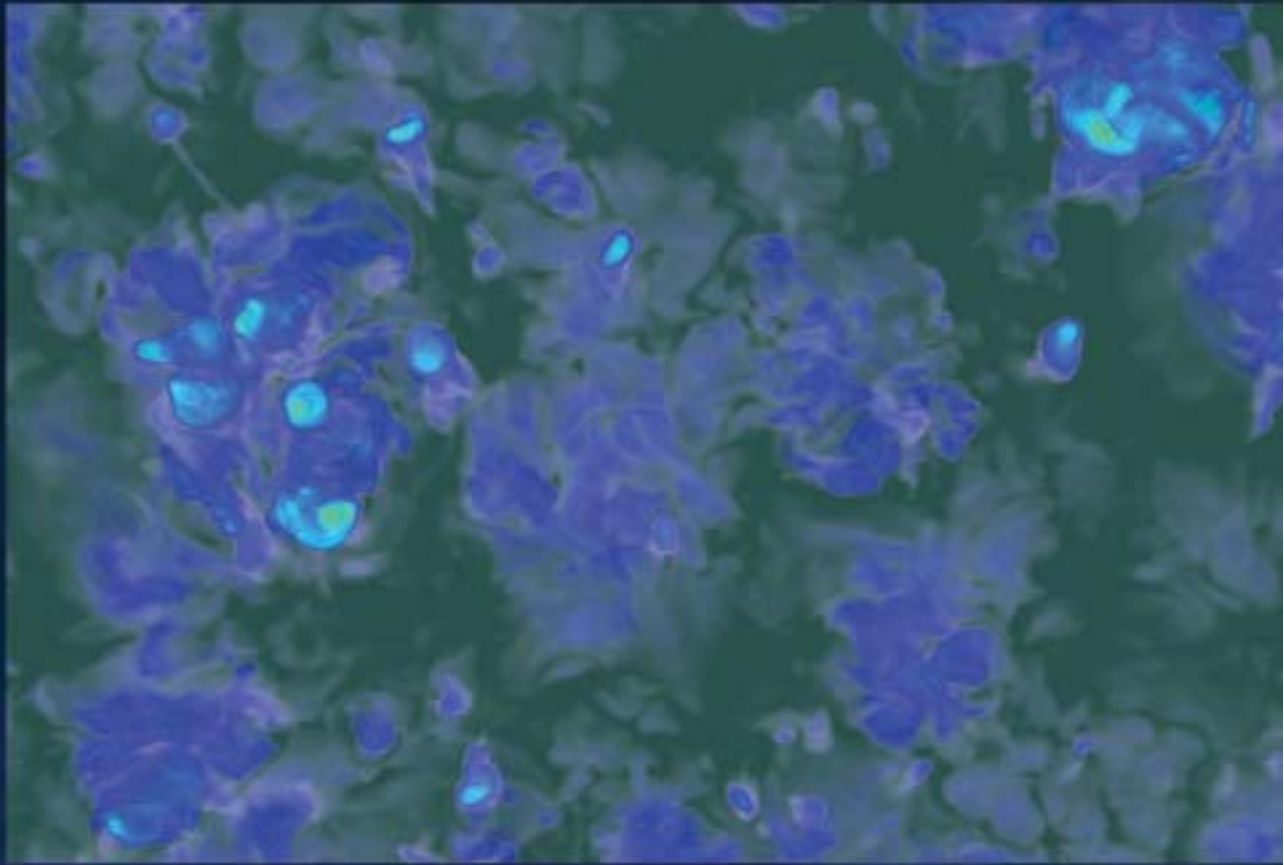
- *Passion for Mission.*
- *Integrity and responsible stewardship of the public trust.*
- *Simultaneous excellence in science and technology, operations, and business practices.*
- *Balancing innovation with disciplined execution.*
- *Teamwork while preserving individual initiative.*
- *Intense competition of ideas with respect for individuals.*
- *Treating each other with dignity.*
- *A high-quality, motivated workforce with diverse ideas, skills, and backgrounds.*
- *Rewarding and recognizing performance.*
- *Commitment to the collective success of the Laboratory.*



SECTION 1

Institutional Plan FY 2003–2008

Laboratory Overview



An unprecedented perspective of turbulent convection of simulated cumulus clouds (viewed from the top). This turbulent mixing calculation, which was performed to test the ASCI White supercomputer when it first arrived in Livermore, used 1,008 processors and 1.3 terabytes of memory. The simulation combines a large domain and small-grid resolution of up to 2.5 billion grid cells.

AT Lawrence Livermore National Laboratory, we are ensuring national security and applying science and technology to the important problems of our time.

Lawrence Livermore National Laboratory was founded in 1952 as a nuclear weapons laboratory. National security continues to be Livermore's defining mission. The Laboratory has been administered since its inception by the University of California (UC), first for the Atomic Energy Commission and now for the National Nuclear Security Administration (NNSA) within the U.S. Department of Energy (DOE). Through its long association with the University of California, the Laboratory has been able to recruit a world-class workforce and to establish an atmosphere of intellectual innovation, which is essential to sustained scientific and technical excellence. As an NNSA laboratory with security and science central to its purpose, Livermore has an essential and compelling core mission and the capabilities to solve important, difficult, real-world problems.

Mission-Supporting Accomplishments.

As this *Institutional Plan FY 2003–2008* highlights, our mission is clear, and the Laboratory is meeting important commitments to our sponsors (Figure 1-1). We are responsible for ensuring the performance of weapon systems in the U.S. nuclear stockpile and for bringing into operation and applying significant new capabilities required for nuclear weapons stockpile stewardship. The stockpile life extension program for the W87 ICBM warhead is well into the production phase, and we have begun activities to extend the life of the W80 cruise missile warhead. The 12-trillion-operations-per-second ASCI White computer at Livermore is supporting the efforts of all three NNSA laboratories—Livermore, Los Alamos, and Sandia—in

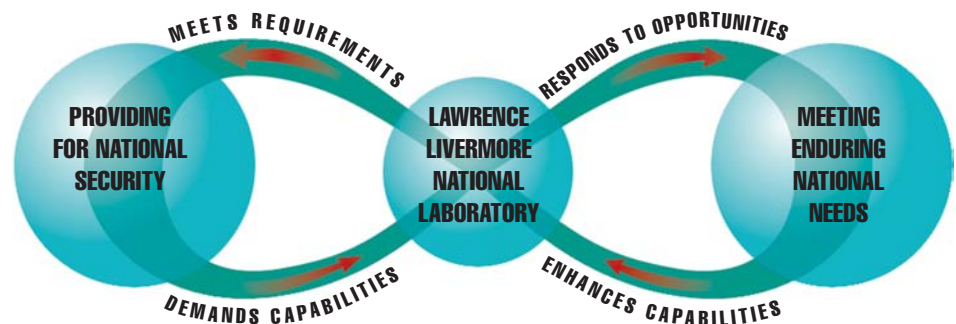


Figure 1-1. The Laboratory's mission. We meet requirements to provide for national security. This mission demands capabilities at the Laboratory that are used to respond to opportunities to meet enduring national needs through projects that enhance our capabilities.

achieving Advanced Simulation and Computing (ASCI) program milestones. The Contained Firing Facility has begun operations, and the National Ignition Facility will achieve early light to the target chamber in FY 2003.

Livermore is supporting U.S. nonproliferation objectives and contributing to the war against terrorism by developing technologies and analytic capabilities. For example, advanced biodetector technologies developed at Livermore are contributing to homeland defense as is the Biological Aerosol Sentry and Information System (BASIS), which was developed by Livermore and Los Alamos and deployed at the 2002 Winter Olympic Games in Salt Lake City. In addition, two analytic tools developed by Livermore, the Counterproliferation Analysis and Planning System (CAPS) and the Joint Conflict and Tactical Simulation (JCATS), are now widely used by the defense community.

This Institutional Plan provides other examples of important achievements—including accomplishments in our major efforts in energy and environment, bioscience and biotechnology, and basic science—that complement our national security mission.

Changes in Our Environment. The events of September 11, 2001, greatly affect the U.S. and all national security activities and organizations—increasing the importance and visibility of our research activities and leading to the creation of the Department of Homeland Security, a new sponsor of work at the Laboratory. We are also adjusting to organizational changes in NNSA, which includes Livermore as one of its three national security laboratories. We are working with NNSA to implement initiatives to streamline operations and further improve NNSA-wide program planning and execution. The Laboratory continues to be managed by the University of California; however, the contract between DOE/NNSA and UC was restructured when it was extended in January 2001. There are greater demands on UC for oversight and higher expectations for Laboratory performance in areas such as safety and security. In addition, there have been many changes in the Laboratory's senior management team. In 2002, a new Laboratory director was selected, and there are two new deputy directors. Altogether, 11 of 17 Laboratory senior managers were appointed to their current positions within the last two years.

The Livermore Approach to Problem Solving

Multidisciplinary Research Teams. We form multidisciplinary teams tailored to meet the demands of each challenging problem. The teams combine scientific and engineering talent, and they draw from a diverse mixture of knowledge, skills, and experience to generate innovative solutions. Increasingly, research efforts entail partnerships with others outside the Laboratory.

An Integrated Approach to Research and Development. Research and development activities at Livermore range from fundamental science to production engineering of complex systems. We carry concepts all the way from scientific discovery to fully developed prototype products.

Large-Scale Experimental Science and Engineering Development. We design and develop technical products for our customers as well as large-scale experimental facilities, which we then use as tools to achieve program goals.

Computer Simulation of Complex Systems. Computer simulation is a cost-effective means for “conducting” a large number of complex experiments. Confidence in modeling results depends on careful validation through actual experiments. These simulations and experiments are mutually reinforcing.

1.1 Mission, Vision, and Goals

1.1.1 Mission

Lawrence Livermore National Laboratory is a premier applied-science national security laboratory. Our primary mission is to ensure that the nation’s nuclear weapons remain safe, secure, and reliable and to prevent the spread and use of nuclear weapons worldwide. This mission enables our programs in advanced defense technologies, energy, environment, biosciences, and basic science to apply Livermore’s unique capabilities and to enhance the competencies needed for our national security mission. The Laboratory serves as a resource to the U.S. government and a partner with industry and academia.

1.1.2 Vision and Goals

Our goal is to apply the very best science and technology to enhance the security and well being of the nation.

A Focus on National Security

National security is the defining responsibility of Lawrence Livermore National Laboratory. We are focusing the Laboratory’s efforts on two of the nation’s top priorities: ensuring the safety, security, and reliability of the U.S. nuclear stockpile and reducing the threats posed by weapons of mass destruction. We will continue to provide the world-class scientific and engineering capabilities that make it possible for the U.S. to maintain its national nuclear deterrent. The war against terrorism makes clear the importance of our efforts to stem the proliferation of weapons of mass destruction and combat their use against the nation and U.S. interests.

The Laboratory’s national security mission presents significant challenges.

As part of an integrated national effort, we must make major advances in science and technology to maintain confidence in the U.S. nuclear weapons stockpile in the absence of nuclear testing. Drawing on these advances and the special expertise of the Laboratory, we also work with various U.S. government agencies to improve international nuclear safety and prevent the proliferation and use of nuclear, chemical, and biological weapons by developing needed technologies and analysis tools. Because of the exceptional scientific and engineering capabilities present at the Laboratory to meet these needs, Livermore is a national resource to assist in the war against terrorism. We take a customer-focused, systems approach to the development of advanced technologies to increase homeland security and the effectiveness of U.S. military forces.

Major Investments at Livermore

At the Laboratory, investments are being made in cutting-edge computational and experimental tools needed to help ensure that the U.S. nuclear weapons stockpile remains safe and reliable. Livermore will have scientific computing capabilities that offer the potential for revolutionary advances in many areas of science and technology as we make necessary improvements to simulation models of nuclear weapons performance. Livermore is also the site for the National Ignition Facility, which will be the world’s largest laser system and will provide the means for investigating the thermonuclear physics of weapons, exploring the promise of fusion energy, and advancing science on many fronts (Figure 1-2). These major investments are shaping the future of the Laboratory.

Meeting Enduring National Needs

An exceptional staff with state-of-the-art research capabilities enables the Laboratory to respond to a broad range of vital national needs. With Livermore's emphasis on high-payoff results, many projects entail significant scientific and technical risk. We seek such challenges where Laboratory efforts can lead to dramatic benefits for the nation.

We focus on the enduring missions of the Department of Energy and the program areas that positively reinforce our national security work. Livermore pursues projects aimed at significant, large-scale innovations in energy production to ensure abundant and affordable energy for the future. Environmental efforts are being directed at demonstrating effective remediation technologies, advancing the science base for environmental regulation, and modeling more accurately regional weather and global climate conditions. We also serve as an effective national technical resource for the management of nuclear systems and materials.

The Laboratory's bioscience research is enhancing the nation's health and security through technological innovation. We leverage our physical science and engineering capabilities and focus on molecular biology, genetics, computational biology, biotechnology, and health-care research. Our basic and applied bioscience research efforts are directed at meeting vital national needs—understanding causes and mechanisms of ill health, developing biodefense capabilities for homeland security, improving disease prevention, and lowering health-care costs. In other fields, Livermore researchers pursue science and technology initiatives that have the potential for major advances and that bolster the Laboratory's

scientific and technological strengths. Increasingly, our accomplishments are being achieved through effective partnerships with others.

Focused Internal Investments

The foundation for Livermore's diverse set of research and development activities—now and in the future—is the Laboratory's science and technology base. Excellence in science and technology keeps the Laboratory vibrant and healthy and able to respond to new challenges. We will sustain our science and technology base through effectively managed internal investments in long-term research activities (such as Laboratory Directed Research and Development projects), research capabilities (such as terascale computers), and the Laboratory's infrastructure to provide an accommodating, modern work environment.

Investments in the Laboratory's staff are also critically important. Our scientific and technical successes would not be possible without the dedicated, outstanding efforts of all employees. We must continue to attract and retain a diverse, high-quality staff for future achievements. Employee development—ranging from continuing education to

leadership and management training for supervisors—is a key part of our investment strategy. We must ensure that employees have the best skills, training, and tools to accomplish their current work and to prepare for career growth.

Safe, Secure, and Efficient Operations

Livermore's scientific and technological achievements are made possible by safe, secure, and efficient operations and sound business practices.

Safety and security are the most important considerations in day-to-day operations. The Laboratory is committed to providing every employee and the community with a safe and healthy environment in which to work and live. Through the implementation of Integrated Safety Management and soon-to-be-implemented Integrated Safeguards and Security Management, we will ensure that safety and security stay a top priority at the Laboratory. Our response to the terrorist attacks on September 11 included swift actions to enhance the security of the Laboratory and to reevaluate what additional security measures are appropriate in view of the changed threat. Livermore

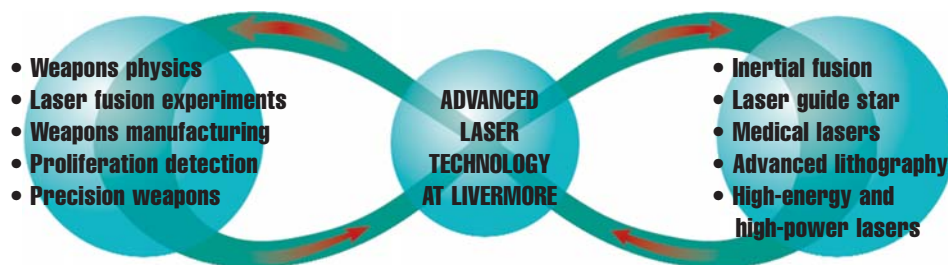


Figure 1-2. Expertise in advanced lasers and associated technologies, necessary for the National Ignition Facility and other major projects for national security, provides program opportunities in inertial confinement fusion, advanced lithography, and other diverse scientific and industrial applications.

now operates routinely at heightened security.

In addition, through a concerted, long-term effort to improve operations and reduce support and overhead costs, Laboratory business services are now faster, better, cheaper, and safer. Livermore has adopted best commercial practices whenever possible and has greatly improved business information systems by taking advantage of rapid

changes in information technology. We will continue to strive for improvement.

1.2 Critical Capabilities

The Laboratory is a national resource with an extensive science and technology base and many specialized research capabilities and facilities. Livermore provides leadership in several

broad research areas that are central to the Laboratory's mission.

1.2.1 An Extensive Science and Technology Base

Livermore programs are supported by a large technical base with nearly 3,000 scientists and engineers serving as career or term employees. A significant portion of the scientific staff is organized

Principal Research Centers and Facilities at Livermore

Center for Accelerator Mass Spectrometry—most versatile spectrometry capability in the world.

Chemistry and Materials Science Environmental Services Laboratory—wide-ranging chemical and radiochemical characterizations of environmental samples.

Computer Incident Advisory Center—DOE's watch and warning center for computer network defense.

Conflict Simulation Laboratory—state-of-the-art, interactive, entity-level conflict simulations.

Electron Beam Ion Trap Facility—unique facility for the study of highly ionized atoms at rest.

Engineering Technology Centers—cutting-edge research in centers for Complex Distributed Systems, Computational Engineering, Microtechnology, Nondestructive Evaluation, and Precision Engineering.

Falcon Laser/Linac—facility for developing a source of ultrafast-pulse x rays.

Flash X-Ray/Contained Firing Facility—versatile hydrodynamic testing facility currently completing upgrades.

Forensic Science Center—world-leading forensic analysis and instrumentation.

Genome Center—facility for high-throughput genome sequencing and study of functional genomics.

Hardened Test Facility—capability for mechanical testing of weapons components.

High-Explosives Applications Facility—world's most modern high-explosives research facility.

Information Operations and Assurance Center—models and visualizations of information networks; analysis and simulations of attacks and responses.

International Assessments Center—national resource for evaluations of foreign weapons programs.

Large Optics Diamond Turning Machine—world's most accurate machine tool for fabricating large metal optical parts.

Long-Term Corrosion Test Facility—comprehensive evaluation service for corrosion on various candidate metals for nuclear waste containers.

National Atmospheric Release Advisory Center—real-time emergency predictions of hazardous substance releases.

4-MeV Pelletron—versatile particle accelerator for materials analysis and radiation effects studies.

Plutonium Facility—modern facility for nuclear materials research and testing.

Positron Microscope—world's most intense pulsed proton beam for studying material defects.

Secure and Open Computing Facilities—supercomputers and testbed for hardware and software development.

300-keV Transmission Electron Microscope—near-atomic-level chemical and structural analyses and images of complex materials.

Tritium Facility—activities to support target fabrication and decommissioning and recycling in inertial confinement fusion.

Two-Stage Gas Guns—phase-change predictions through experiments with metallic hydrogen.

Ultrashort-Pulse Laser—capability for equation-of-state, opacity, and other stockpile stewardship experiments.

Uranium Manufacturing and Process Development Facility—research facility for casting and forming processes.

into “discipline” directorates—Chemistry and Materials Science, Computation, Engineering, and Physics and Advanced Technologies—and many of these people are matrixed, or assigned, to specific programs. Use of the matrix system fosters efficient transfer of technical knowledge among programs, enables staff members to develop wide-ranging skills and knowledge, and infuses projects with diverse ideas for solutions. As a result, the Laboratory has the ability to seize program opportunities, the agility to react quickly to technical surprises, and the flexibility to respond to programmatic changes.

The Laboratory’s many research and development accomplishments demonstrate Livermore’s leadership in several broad research areas. **High-Energy-Density Physics, Ignition Physics, and Nuclear Science and Technology.** For 50 years, the Laboratory has demonstrated excellence in science and technology directed at the development of nuclear weapons and the harnessing of thermonuclear and fission energy for civilian power generation. We have broad expertise in nuclear science and technology as well as exceptional capabilities for investigating the properties of matter at

extreme conditions (up to stellar temperatures and pressures) and the interaction of matter with intense radiation. This expertise will remain crucial for our national security programs. It will also be applied to assist DOE and NNSA in the management of nuclear materials, improve technology for nuclear systems, develop innovative techniques for environmental cleanup, and advance fundamental science in many areas. **Advanced Lasers and Electro-Optics.** Livermore is the preeminent laser science and technology laboratory in the world. We are strongly focused on

From Creating the Laboratory’s Future . . .

PROVIDING FOR NATIONAL SECURITY

“National security is the defining responsibility of the Laboratory.”

MEETING ENDURING NATIONAL NEEDS

“Our focus will remain on the critical, enduring missions of the DOE and program areas that positively reinforce our national security work.”

MISSION-DIRECTED SCIENCE AND TECHNOLOGY

“Livermore’s strengths are well matched to DOE’s needs. . . . We pursue major projects where we can make unique and valuable contributions. These activities build on and reinforce the Laboratory’s key strengths.”

AN OUTSTANDING WORKFORCE

“Challenging scientific programs, world-class research facilities, and a collegial environment are critical to attracting and retaining an outstanding workforce.”

INVESTING IN THE FUTURE

“Excellence in science and technology will keep the Laboratory vibrant and healthy and able to respond to new challenges.”

MANAGING OPERATIONS EFFECTIVELY

“Safe and efficient operations, sound business practices, and attention to the Laboratory’s valuable resources make possible Livermore’s technical achievements.”

PARTNERSHIPS THAT CREATE CAPABILITIES

“We are involved in collaborations as a means to accomplish our goals, an expansion of the original E. O. Lawrence model of team science.”

meeting construction goals for the National Ignition Facility, bringing laser beams into operation expeditiously, and starting experimental activities. We also apply the Laboratory's expertise in lasers and electro-optics to meet other national needs, contribute to the competitiveness of U.S. industry, and address issues in basic science (Figure 1-2).

High-Performance Scientific

Computing. As part of the Advanced Simulation and Computing Program (still abbreviated as ASCI, but formerly called Accelerated Strategic Computing Initiative), we are acquiring successively more powerful computers with the goal of dramatically increasing computational speed and data capacity. The 12-teraops (12 trillion operations per second) ASCI White supercomputer at Livermore is supporting stockpile stewardship simulation efforts at all three NNSA laboratories. Construction has started on the Terascale Simulation Facility, which will house ASCI Purple, a machine that will be capable of 100 teraops. In November 2002, IBM was awarded the contract to build the ASCI Purple system and an advanced research machine called Blue Gene/L, also to be sited at Livermore. With ASCI Purple, the NNSA laboratories will have for the first time enough computing power and memory to complete high-fidelity-physics calculations of the explosion of a full weapons system with three-dimensional (3D) features.

In addition to meeting the Laboratory's commitments to national security programs, we are making internal investments to ensure that all major programs at the Laboratory have access to terascale computers. These capabilities can potentially revolutionize scientific discovery and lead to

unprecedented levels of understanding in biology and environmental science, improved modeling of weather and climate, the design of new materials, and advances in many areas of physics.

Materials Science. In support of Laboratory programs, we have developed wide-ranging expertise about materials. In addition to conducting fundamental research on the properties of materials, we engineer novel materials at the atomic or near-atomic levels. Livermore's stockpile stewardship responsibilities require researchers to understand in great detail the properties of very complex materials—ranging from plutonium to organic materials, such as high explosives—and how materials age in the presence of radiation and toxic materials.

Expertise in chemistry and materials science also provides critical support to many other Laboratory programs, such as environmental cleanup, nuclear waste disposal, and atmospheric modeling. In addition, we develop nanoengineered multilayer materials and other exotic materials, such as aerogels. These advances meet programmatic needs for highly efficient energy-storage components, ultralight structural materials, tailored coatings, and novel electronic, magnetic, and optical materials.

1.2.2 Specialized Research Capabilities and Facilities

Many specialized research capabilities and facilities exist at Livermore. Because of our overall size, the need for technologies and capabilities that do not exist elsewhere, and the fact that essential elements of our national security mission are classified, much of the necessary

expertise to support programs resides within the Laboratory. For example, we have capabilities to develop state-of-the-art instrumentation for detecting, measuring, and analyzing a wide range of physical events. We also have significant expertise to support innovative applied-science efforts in advanced materials: precision engineering, microfabrication, nondestructive evaluation, complex-system control and automation, and chemical, biological, and photon processes.

1.2.3 Multiprogram Support for DOE

As a consequence of the Laboratory's extensive science and technology base and its many special research capabilities, we provide multiprogram support to DOE. This important relationship between the capabilities that Livermore has developed to fulfill its national security mission and its ability to make unique and valuable contributions in other DOE mission areas is a central feature of Livermore's mission statement (Figure 1-1).

For example, with outstanding capabilities in laser science and technology, we support stockpile stewardship, pursue inertial confinement fusion physics, develop lasers for biotechnology and advanced manufacturing applications, and apply advances in laser technology to make breakthroughs in areas of basic science (Figure 1-2). Our expertise in bioscience and bioengineering can be applied to genomics research, bioremediation, environmental risk reduction, and biological warfare agent detection. Advanced scientific computing at Livermore supports stockpile stewardship, atmospheric modeling for emergency response and global climate prediction,

computational biology, modeling for radioactive waste disposition and the movement of contaminants in groundwater, materials science modeling, and many other scientific areas (Figure 1-3).

1.2.4 Critical Skills in the Workforce

The Laboratory's principal asset is a skilled and dedicated workforce—since the inception of the Laboratory and continuing into the future. The programmatic achievements of the Laboratory would not be possible without the concerted efforts of employees from across the institution—delivering breakthrough technical research or providing critical operational and administrative support. Our employees' technical and scientific excellence has resulted in the many awards and honors highlighted in the Laboratory's *Annual Report*.

More and more, flexibility is a recurring theme in our efforts to ensure we have the optimal workforce with the skills to meet the Laboratory's needs. As the nation's security needs change and Laboratory missions evolve accordingly, we must acquire new skills as we maintain expert knowledge and judgment about nuclear weapons issues. Adjusting to and effectively managing changing demographics of the Laboratory workforce also require flexibility. We must be able to retain our experienced and critically skilled employees while competing for newly trained professionals who will sustain our programs in the future. To assess the specific situation and issues in each of the Laboratory's directorates, a series of workforce reviews was requested by the new Director and completed in 2002. Such reviews will be held in the future on an annual basis.

With recruitment and retention as a driving consideration, the Laboratory completed a comprehensive workforce survey in 2001. Survey results were used to develop a set of recommendations in seven focus areas to significantly enhance our work environment and make the Laboratory an even more desirable employer for our future workforce. Implementation of these recommendations is under way.

1.3 Strategy Development and Alignment

1.3.1 The Strategic Direction of DOE

The strategic direction of the Department of Energy was clearly defined by DOE Secretary Spencer Abraham in his post-September 11 remarks at the DOE Quarterly Leadership Meeting in October 2001. He stated that, "In my view, the starting place is to understand that our overarching mission is national security." Supporting information about DOE's strategic direction is provided in the *Department of Energy Annual Performance Plan FY 2002*, the *Department of Energy Performance*

and Accountability Report FY 2001, the *NNSA Strategic Plan*, and the *National Energy Strategy*. The *NNSA Strategic Plan*, issued in February 2002, reflects the results of the Nuclear Posture Review, which was completed in 2001. The most recent *Department of Energy Strategic Plan* was issued in September 2000.

DOE Mission and Priorities. As articulated by Secretary Abraham in October 2001, the Department of Energy's overarching mission is to enhance national security. Responsibility for accomplishing this mission is shared among four principal business lines: National Nuclear Security, Energy Resources, Environmental Quality, and Science. DOE's general goals in each of these areas (and in Corporate Management) are as follows:

- National Nuclear Security: Enhance national security through the military application of nuclear technology and reduce the global danger from weapons of mass destruction.
- Energy Resources: Promote the development and deployment of energy systems and practices that will provide current and future generations with energy that is clean, efficient, reasonably priced, and reliable.



Figure 1-3. The Advanced Simulation and Computing (ASCI) Program and Livermore's advanced scientific computing capabilities, required for stockpile stewardship, enable us to respond to other program opportunities.

Table 1-1. Alignment of the DOE Strategic Objectives with Livermore's Top Institutional Objectives.

DOE Strategic Objectives	Livermore Objectives ^a
National Nuclear Security	
NS1: Maintain and refurbish nuclear weapons in accordance with directed schedules to sustain confidence in their safety, security, and reliability, indefinitely, under the nuclear testing moratorium and arms reduction treaties.	1,2,4,7
NS2: Achieve the robust and vital scientific, engineering, and manufacturing capability that is needed for current and future certification of the nuclear weapons stockpile and the manufacture of nuclear weapons components under the nuclear testing moratorium.	1,2,4,7,9
NS3: Ensure the vitality and readiness of DOE's national nuclear security enterprise.	1,2,5,7,9
NS4: Reduce the global danger from the proliferation of weapons of mass destruction (WMD).	1,3,7
NS6: Ensure that the Department's nuclear weapons materials, facilities, and information assets are secure through effective safeguards and security policy, implementation, and oversight.	1,8,9
Energy Resources	
ER3: Increase the efficiency and productivity of energy use, while limiting environmental impacts.	1,7,10
ER5: Cooperate globally on international energy issues.	1,7,10
Environmental Quality	
EQ1: Safely and expeditiously clean up sites across the country where DOE conducted nuclear weapons research, production, and testing or where DOE conducted nuclear energy and basic science research. After completion of cleanup, continue stewardship activities to ensure that human health and the environment are protected.	1,8,9,10
EQ2: Complete characterization of the Yucca Mountain site and, assuming it is determined suitable as a repository and the President and Congress approve, obtain requisite licenses, construct, and in FY 2010, begin acceptance of spent nuclear fuel and high-level radioactive wastes at the repository.	1,7,10
Science	
SC1: Provide the leadership, foundations, and breakthroughs in the physical sciences that will sustain advancements in our nation's quest for clean, affordable, and abundant energy.	1,4,7,10
SC2: Develop the scientific foundations to understand and protect our living planet from the adverse impacts of energy supply and use, support long-term environmental cleanup and management at DOE sites, and contribute core competencies to interagency research and national challenges in the biological and environmental sciences.	1,7,10
SC3: Explore matter and energy as elementary building blocks from atoms to life, expanding our knowledge of the most fundamental laws of nature, spanning scales from the infinitesimally small to the infinitely large.	1,4,6,7,10
SC4: Provide the extraordinary tools, scientific workforce, and multidisciplinary research infrastructure that ensure success of DOE's science mission; and support our nation's leadership in the physical, biological, environmental, and computational sciences.	1,4,7,9,10
Corporate Management	
CM1: Ensure the safety and health of the DOE workforce and members of the public and the protection of the environment in all Departmental activities.	1,6,8
CM2: Manage human resources and diversity initiatives and implement practices to improve the delivery of products and services.	1,5,6,8
CM3: Manage financial resources and physical assets to ensure public confidence.	1,8,9
CM4: Manage information technology systems and infrastructure to improve the Department's efficiency and effectiveness.	1,8,9
CM5: Use appropriate oversight systems to promote the efficient, effective, and economical operation of the Department of Energy.	1,6,8

^aFrom Table 1-3.

- **Environmental Quality:** Aggressively clean up the environmental legacy of nuclear weapons and civilian nuclear research and development programs at the Department's remaining sites, safely manage nuclear materials and spent nuclear fuel, and permanently dispose of the nation's radioactive wastes.

- **Science:** Advance the basic research and instruments of science that are the foundations for DOE's applied missions, a base for U.S. technology innovation, and a source of remarkable insights into our physical and biological world and the nature of matter and energy.

- **Corporate Management:** Demonstrate excellence in the Department's environmental, safety, and health practices and management systems that support our world-class programs.

The strategic objectives of the DOE are further articulated in the *DOE FY 2001 Performance and Accountability Report* (February 2002), which was prepared by the Department to meet requirements of the Governmental Performance and Results Act (GPRA) of 1993. The document, which is issued annually, provides performance results in terms of 51 general performance goals that are tied to 23 general goals. These general goals are used in Table 1-1 to illustrate alignment of Livermore's priorities with those of DOE.

The Nuclear Posture Review. In January 2001, President Bush asked the Secretary of Defense to conduct three reviews to create a new vision for the role of the nation's military in the 21st century. The Nuclear Posture Review (NPR), which was delivered by the Administration to Congress in January 2002, provides an in-depth review of future national security needs and describes elements of the nuclear weapons stockpile and infrastructure required to support them. The NPR reaffirms that nuclear weapons, for the foreseeable future, will remain a key element of U.S. national security

strategy. The NPR also endorses current NNSA plans for refurbishing the stockpile and NNSA initiatives in the areas of enhancing test readiness, re-establishing advanced concepts groups at the laboratories, and beginning design work on a modern pit factory.

The NNSA Strategic Plan. The *NNSA Strategic Plan* aligns with the results from the Administration's Nuclear

Posture Review and outlines NNSA's vision for the next 15 years. It specifies the core values, mission, and vision together with goals, strategies, and strategic indicators. NNSA's strategic goals and supporting strategies, indicating areas where the Laboratory provides considerable support, are listed in Table 1-2.

The National Energy Policy. *National*

Table 1-2. NNSA's Goals and Strategies That Livermore Supports.

Goals	Strategies
1. Maintain and enhance the safety, security, and reliability of the nation's nuclear weapons stockpile to counter the threats of the 21st century.	<ul style="list-style-type: none"> • Conduct a program of warhead evaluation, maintenance, refurbishment, and production, planned in partnership with the Department of Defense. • Develop science, design, engineering, testing, and manufacturing capabilities needed for long-term stewardship of the stockpile.
2. Detect, prevent, and reverse the proliferation of weapons of mass destruction while promoting nuclear safety worldwide.	<ul style="list-style-type: none"> • Enhance the capability to detect weapons of mass destruction, including nuclear, chemical, and biological systems and terrorist threats. • Prevent and reverse proliferation of weapons of mass destruction. • Protect or eliminate weapons and weapons-usable nuclear material and/or infrastructure, and redirect excess foreign weapons expertise to civilian enterprises. • Reduce the risk of accidents in nuclear-fuel-cycle facilities worldwide.
3. Ensure the vitality and readiness of NNSA's nuclear security enterprise.	<ul style="list-style-type: none"> • Ensure the safety, performance, reliability, and service life of operating reactors. • Develop new technologies, methods, and materials to support reactor plant design for the next-generation reactors for submarines and aircraft carriers. • Maintain outstanding environmental performance.
4. Create a well-managed, responsive, and accountable organization.	<ul style="list-style-type: none"> • Attract and retain the best laboratory and production workforce. • Provide state-of-the-art facilities and infrastructure supported by advanced scientific and technical tools to meet operational and mission requirements. • Protect classified information and assets.

Energy Policy, the report of the National Energy Policy Development Group (May 2001), provides to the President a series of recommendations to promote dependable, affordable, and environmentally sound energy for the future. The report envisions an integrated energy, environmental, and economic policy that builds on a comprehensive long-term strategy in which leading-edge technology will be used to provide reliable energy and a clean environment. The policy is designed to bring together the efforts of business, government, local communities, and citizens. It will lead to new demands on the research and development capabilities of DOE and its national laboratories.

1.3.2 The Laboratory's Strategy

Livermore's Strategy Document. The Laboratory's strategy document, *Creating the Laboratory's Future*, provides the basis for this Institutional Plan. *Creating the Laboratory's Future* reflects our view of Livermore's responsibilities in meeting the strategic goals of DOE. The Laboratory's strategy was developed through the efforts of the five strategic councils at the Laboratory and the Policy, Planning, and Special Studies Office, which took the lead in synthesizing the work of the councils for senior management review.

Creating the Laboratory's Future describes Livermore's roles and responsibilities as a DOE/NNSA national laboratory and sets the foundation for decisions about Laboratory programs and operations. It presents the Laboratory's mission, vision, and goals (see Section 1.1); work projects and initiatives in support of them; the science and technology

strengths of the Laboratory that support our missions (Section 1.2); the management of operations at the Laboratory (and operations initiatives); and steps we are taking to prepare for the future.

Top Institutional Objectives. As an extension to *Creating the Laboratory's Future*, a list of the Laboratory's top priorities identifies institutional objectives for FY 2003 (Table 1-3). The first objective on the list—delivering on the performance measures in the DOE–UC management and operating contract (Table 1-4)—includes key short- and long-term priorities that will be used by UC and NNSA to assess the Laboratory's performance (see

Section 1.4). The other 10 priorities on the list represent specific goals for FY 2003 or are institutional issues that will be the focus of special attention this year. Other important objectives for specific programs are not included. Our achievement of these objectives will help to strengthen the Laboratory as an institution and define long-term well-defined roles in program areas that are of national interest and importance.

Management Changes at Livermore. With the appointment of 11 new associate director–level managers in 2001 and 2002, most of the vacant senior management positions have been filled. Our new Director, Michael R. Anastasio, began service on

Table 1-3. Livermore's Top Institutional Objectives for FY 2003.

1. Deliver on the nine strategic objectives identified in the DOE–UC management and operating contract (see Table 1-4).
2. Meet nuclear weapons program commitments; implement actions resulting from the Nuclear Posture Review.
3. Establish and execute our research, development, testing, and evaluation responsibilities for the Department of Homeland Security.
4. Sustain the National Ignition Facility (NIF) project on track; achieve first light at NIF and perform the first successful experiments.
5. Develop a science and technology investment strategy.
6. Implement recommendations from the employee survey and address workforce development issues.
7. Continue to provide a safe and secure workplace, and increase effectiveness and flexibility of the Laboratory's operations.
8. Award ASCI Purple contract and continue our leadership in supercomputing.
9. Complete the senior management team and strengthen partnerships across organizations.
10. Refine the Laboratory's strategies to pursue national missions in bioscience and health, energy, and environment and to support the efforts of the Department of Defense and other national security agencies.
11. Implement actions to achieve the goals of the Laboratory's *Ten Year Comprehensive Site Plan* and evolve the plan to meet arising needs.

July 1, 2002. However, several key positions are filled on an acting basis, and one of the Director's top priorities is to complete his management team. (See Section 5.2 for a current organization chart.)

1.3.3 Alignment with DOE Strategy and Needs

Livermore's Principal Responsibilities and Major Programs. The Laboratory's mission statement—and essentially all the supporting material in *Creating the Laboratory's Future*—highlights the important interaction among Livermore's primary (national security) mission, the scientific and technical capabilities at the Laboratory, and programs to meet other enduring national needs. The direction of the Laboratory's national security programs—evident from the top institutional objectives—is discussed in Section 2 of this Institutional Plan. In providing for national security, Livermore's principal responsibilities are:

- Stewardship of the U.S. nuclear weapons stockpile.
- Stemming the proliferation of weapons of mass destruction.
- Responding to other important national security needs through the application of Livermore's science and technology.

Requirements to provide for national security demand unique capabilities at the Laboratory, which are also used to respond to opportunities to meet broader national needs. As discussed in Section 3 of this Institutional Plan, our focus is on the critical, enduring missions of DOE and program areas that reinforce our national security work. Where we can make unique and valuable contributions, Livermore pursues major projects for:

- Energy security and long-term energy needs.

Table 1-4. The Nine Strategic Objectives in the DOE–UC Management and Operating Contract.

- Develop and implement a common UC design laboratory weapon certification strategy.
- Develop with NNSA and implement long-term balanced, integrated stockpile stewardship.
- Develop with NNSA and implement near-term balanced weapon program plans.
- Develop and implement a sound nonproliferation/counterterrorism basis.
- Enhance and nurture a strong science base in support of NNSA strategic objectives.
- Achieve successful completion of projects and development of user facilities.
- Maintain an effective and efficient operations basis in support of mission objectives.
- Utilize UC strengths to recruit, retain and develop the workforce.
- Sustain effective community initiative.

- Environmental assessment and management.
- Bioscience to enhance the nation's health and security.
- Breakthroughs in fundamental science and technology.

We are able to make selected advances in many of DOE's mission areas, in part because our approach to research and development is multidisciplinary, integrating many disciplines with cutting-edge capabilities in multiple areas of science and technology. Laboratory scientists contribute to advances in many areas, including nuclear and atomic physics, astrophysics, laser science and technology, materials science, geoscience, atmospheric sciences, biology, and high-performance computing. In addition, Livermore's engineering capabilities make possible the development of a variety of advanced sensors and detectors, prototype systems,

and one-of-a-kind capabilities or facilities.

For example, Livermore's Biology and Biotechnology Research Program is at the forefront of genomics research in part because of the Laboratory's engineering capabilities and success in developing technologies for high-speed sorting of individual chromosomes and for measuring distances between DNA markers. Bioscience expertise, in turn, is contributing to the development of novel bioremediation technologies for groundwater cleanup and portable mini-sensors for rapid, accurate detection and characterization of biological warfare agents in the field. Opportunities to meet a broad range of national needs are created by our other special capabilities, such as advanced lasers (Figure 1-2) and advanced scientific computing (Figure 1-3).

Alignment with the DOE Strategic Objectives. Continuing interactions of

Livermore programs with DOE sponsors and senior Laboratory managers with DOE program secretarial officers (PSOs) greatly contribute to aligning the Laboratory's strategic direction with that of DOE. Moreover, as exemplified by the Stockpile Stewardship Program, key Laboratory program leaders and staff work with and provide information to assist NNSA and DOE PSOs in formulating DOE's strategic plans and direction. These activities feed back into the Laboratory's strategic planning process and assure that programs and strategies align with those of NNSA and DOE (Figure 1-4). Figures 1-4 and 1-5

illustrate alignment of Livermore's 2002 top objectives with the general goals used in the *DOE FY 2001 Performance and Accountability Report* (February 2002) and Laboratory support to the goals and strategies in the *NNSA Strategic Plan*.

Self-Assessments of Planning Success.

In our self-assessment of Laboratory planning for DOE and the University of California (Section 1.4), we evaluate success and alignment with DOE's strategic direction and plans through consideration of four factors:

- Successful Programs and Partnerships.
- Major Investments at the Laboratory.

- New Initiatives with DOE.
- Awards and Honors.

1.3.4 Support for Homeland Security

Enactment of legislation to form a Department of Homeland Security has fundamentally changed the nation's approach to preventing terrorist attacks on the United States, reducing the nation's vulnerability to terrorism, and managing the aftermath of any attack. The mission is complex and daunting in scope. One major challenge for the new Department will be effective integration of relevant activities, which are currently dispersed among many government organizations. Another challenge will be focusing the unsurpassed scientific and technical talent of this nation to improve capabilities to deal effectively with threats, those most critical today as well as those emerging in the future.

Long before the terrorist attacks of 2001, the Laboratory provided technologies, analyses, and expertise to reduce the threats posed by the proliferation of weapons of mass destruction and their potential acquisition and use by terrorists. Since September 11, many of these capabilities have been applied to improve the nation's defense. The establishment of the Department of Homeland Security presents the Laboratory with the opportunity and responsibility to expand applications of Livermore's outstanding science and technology to counter the threat posed by potential terrorist use of weapons of mass destruction against the United States.

To build a long-term, substantial relationship in support of the Department of Homeland Security, the Laboratory Director has formed a Homeland Security Organization at

Department of Energy Strategic Plan	Creating the Laboratory's Future
National Security Enhance national security through military application of nuclear technology and reduce the global danger from weapons of mass destruction.	<ul style="list-style-type: none"> • Providing for National Security <ul style="list-style-type: none"> – Stewardship of the U.S. nuclear stockpile – Stemming the proliferation of weapons of mass destruction – Meeting new military requirements
Energy Resources Promote the development and deployment of energy systems and practices that will provide current and future generations with energy that is clean, efficient, reasonably priced, and reliable.	<p><i>"National security is the defining responsibility of the Laboratory."</i></p> <p><i>"Our focus will remain on the critical, enduring missions of the DOE and program areas that positively reinforce our national security work."</i></p>
Environmental Quality Aggressively clean up the environmental legacy of nuclear weapons and civilian nuclear research and development programs at DOE's remaining sites, safely manage nuclear materials and spent nuclear fuel, and permanently dispose of the nation's radioactive wastes.	<ul style="list-style-type: none"> • Meeting Enduring National Needs <ul style="list-style-type: none"> – Energy security and long-term energy needs – Environmental assessment and management – Nuclear materials stewardship – Bioscience to advance the nation's health and security – Breakthroughs in fundamental sciences and applied technologies
Science Advance the basic research and instruments of science that are the foundations for DOE's applied missions, a base for U.S. technology innovation, and a source of remarkable insights into our physical and biological world and the nature of matter and energy.	

Figure 1-4. The missions and goals identified in the Laboratory's strategy document, *Creating the Laboratory's Future*, closely align with DOE's strategic objectives.

Livermore that reports directly to him. The Homeland Security Organization will be the focal point for Laboratory interactions with the new Department.

1.3.5 Anticipating and Responding to Future Needs

In addition to its programmatic responsibilities, Livermore—as a national laboratory—serves as a technical resource for the federal government to use in the development of effective public policy. To meet this responsibility, the Laboratory must maintain its vitality by anticipating and changing to meet evolving national needs. We work with DOE and other sponsors to anticipate the future needs of the nation, keep them apprised of emerging technical opportunities, and identify areas where science and technology can enhance security and national well being. To be effective, we must continue to be an integral and active part of the nation's science and technology infrastructure, participate in the national dialogue on important science issues, and be broadly recognized as a scientific leader.

Focused Internal Investments. We must continue to make internal investments that develop the skills and capabilities needed to meet customers' future needs. The present strengths of Livermore are, in large part, a product of investment choices in the past. These include investments in people, research capabilities and infrastructure, and long-term research activities, such as Livermore's Laboratory Directed Research and Development (LDRD) Program. LDRD is an important tool we have for supporting research and development projects that will enhance the Laboratory's core strengths, nurture

research efforts that expand scientific and technical horizons, and create important new capabilities so that the Laboratory can respond promptly and effectively to new missions and national priorities. Livermore's LDRD Program has been very productive since its inception in FY 1985, with an outstanding record of scientific and technical output. Program accomplishments (highlighted in Section 3.3) are more fully described in Livermore's LDRD annual reports.

1.4 Evaluation of Performance

Livermore is one of three national laboratories managed and operated under a contract between the Department of Energy and the University of California (UC). When the DOE–UC contract was revised and extended in 1992, DOE and UC pioneered performance-based contracting as applied to government-owned, contractor-operated (GOCO) institutions. In 1997, DOE and UC extended the contract for five years and made changes to it to strengthen the performance-based management system introduced in 1992. In January 2001, the management and operating contract was modified to extend the contract term for an additional three years, through September 30, 2005.

Appendix F and Performance Measures. Appendix F of the DOE–UC management and operating contract contains performance objectives and measures that provide the basis for the performance management system. Performance has been measured in three areas: (1) Laboratory management, (2) science and technology, and (3) administration and operations, which includes such items as environment,

safety, and health (ES&H); security; business operations; facilities management; and human resources.

As shown in Figure 1-5, since the inception of the performance assessment system in FY 1993, the Laboratory has achieved very high ratings in science and technology and has markedly improved ratings in administration and operations since the first year. Starting in 2001, laboratory management, which had been part of the administration and operations evaluation, received a separate score. Our performance evaluation in FY 2001 was “outstanding” in science and technology, administration and operations, and laboratory management.

Appendix O and Performance Improvements. In January 2001, when the DOE–UC management and operating contract was extended for three years, it underwent a major rewrite. The contract was restructured to strengthen management accountability at UC and the laboratories and to provide for improved performance at Livermore and Los Alamos national laboratories under five Appendix O program performance initiatives: Management Accountability; Safeguards and Security Management; Facilities Safety (including Nuclear Facilities Operations); Critical Skills, Knowledge and Technical Capabilities; and Project Management and Construction Project Management. Successful implementation of Appendix O has had the highest management attention at Livermore, Los Alamos, and the University of California, and we achieved a “green” rating (pass, under a pass/fail evaluation system) for each of the five initiatives.

A New Approach to the Appendix F Self-Assessment Process. The University of California has worked

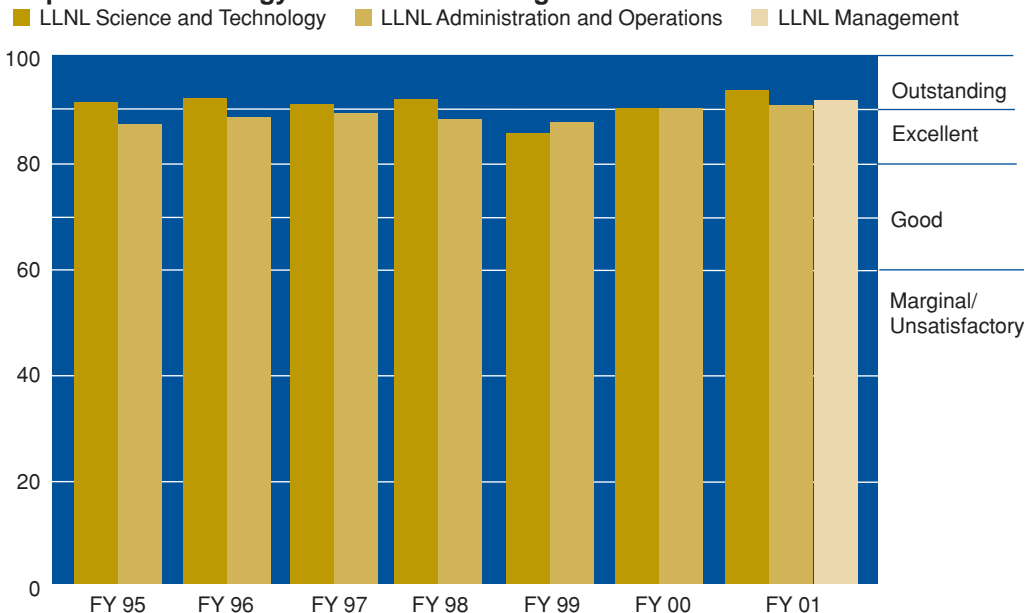
closely with NNSA, Livermore, and Los Alamos to revamp and improve the performance-based management assessment process embodied in Appendix F to the contract. The cornerstone of the new Appendix F process—in place for FY 2003—will be nine major goals that represent key deliverables in programmatic, scientific, and operational areas (see

Figure 1-5). These goals align with and focus on the integrated “A lists” of the NNSA Administrator, the UC Vice President for Laboratory Management, and the laboratory directors. They constitute a balanced set of objectives tied to integrated mission performance, scientific and technical excellence, and operational effectiveness.

The performance evaluation process will help ensure sharp focus on the most important elements of mission execution at the laboratories and reinforce the commitment UC and the laboratory directors have made for stronger lab-to-lab integration and cooperation. Senior management at NNSA, UC, and the laboratories are directly involved throughout the review process.

Figure 1-5. Overall, in FY 2001, Livermore’s Management, Science and Technology (S&T), and Administration and Operations (A&O) were deemed “outstanding” as measured by performance criteria defined in the performance-based management contract between the Department of Energy and the University of California.

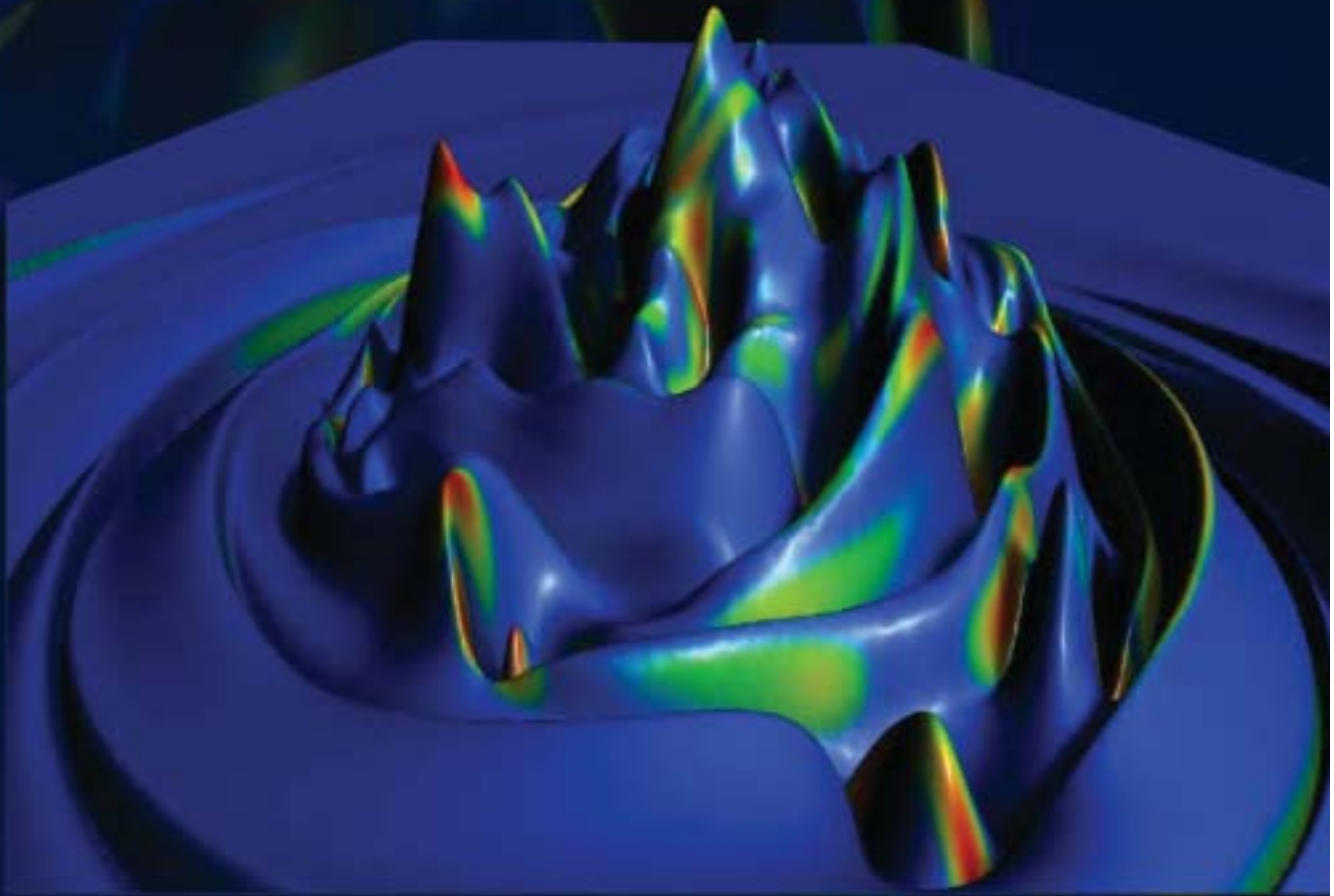
Department of Energy Performance Ratings



SECTION 2

Institutional Plan FY 2003–2008

Laboratory Science and Technology— National Security



The Advanced Simulation and Computing (ASCI) Program's Visual Interactive Environment for Weapons Simulation (VIEWS) is meeting the challenge to provide environments for visually exploring huge (quadrillion-byte) datasets. From the Livermore VIEWS project, this interactive height map visualizes turbulent mixing of fluids of different densities. One of the project's goals is to enable researchers to view such mixtures from various angles as the ASCI White computer calculates the mixing process.

LAURENCE Livermore National Laboratory was founded in 1952 as a nuclear weapons laboratory. National security remains Livermore's defining mission. The world has undergone significant changes since then, and likewise, our mission has become more dynamic and complex.

National security rests on the twin pillars of deterring aggression against the U.S. and its allies—through diplomacy, treaties, and military strength—and reducing the threats posed by others—by stemming the spread and countering the use of weapons of mass destruction (WMD). Both pillars are founded on the bedrock of U.S. scientific and technological superiority. The Laboratory's national security programs, conducted in the context of the overall national and global security environment, provide science and technology to underpin and support U.S. national security policy.

The Laboratory's national security programs align directly with the *Strategic Plan* of DOE's National Nuclear Security Administration (NNSA) and its mission "to strengthen United States' security through the military application of nuclear energy and by reducing the global threat from terrorism and weapons of mass destruction."

Livermore is one of the three national security laboratories that are part of NNSA. Created through Congressional legislation enacted in 1999, NNSA brings together DOE's national security functions. NNSA is responsible for long-range planning and developing comprehensive five-year budget plans for national security activities, and it manages both programmatic and operational activities within DOE/NNSA's nuclear weapons complex.

Stockpile Stewardship

Nuclear deterrence remains a key component of U.S. national security

policy for the foreseeable future, and the maintenance of a safe and reliable nuclear stockpile is a supreme national interest. An early action undertaken by the Bush Administration was a broad review of the U.S. military for the 21st century, including the Nuclear Posture Review, which considered the role of nuclear weapons and nuclear force requirements. The results of the Nuclear Posture Review are reflected in NNSA's *Strategic Plan* and five-year planning for resource, workforce, and facility requirements at its laboratories and production facilities.

Livermore plays a key role in the Stockpile Stewardship Program for maintaining the nation's nuclear weapons stockpile in the absence of nuclear testing. The program consists of an integrated set of activities that provide surveillance of the stockpile, assessment and certification of weapon performance, and refurbishment of weapons as necessary.

The challenges inherent in the Stockpile Stewardship Program will become more difficult as weapons continue to age. Bringing new experimental facilities into operation and accelerating and improving capabilities for high-performance computing with advanced simulation tools are fundamental to the success of the effort. Success also critically depends on maintaining expert judgment about nuclear weapons. We must pay particular attention to workforce recruiting, effective on-the-job training, and retention of highly qualified scientific and technical personnel to meet these challenges.

WMD Threat Reduction

National security is threatened by the spread and potential use of nuclear, chemical, and biological weapons (collectively referred to as weapons of mass destruction, or WMD). At least 20 countries, some of them hostile to U.S. interests, are suspected of or known

to be developing WMD, and there is growing concern about the possible acquisition and use of WMD by terrorist groups such as al Qaeda. The events of September 11, 2001, made glaringly clear the vulnerability of free societies to terrorist-inflicted mass devastation.

Improved scientific and technical capabilities play a critical role in U.S. abilities to reduce the threats posed by the proliferation or terrorist acquisition of WMD. NNSA's Office of Defense Nuclear Nonproliferation has supported most of the research and development activities that provide the technological base for those U.S. agencies with operational responsibility for implementing and monitoring arms control and proliferation prevention agreements, for characterizing foreign weapons programs and detecting proliferation-related activities, and for detecting and mitigating the use of WMD against the U.S.

Livermore is engaged in many of the U.S.–Russian cooperative nonproliferation programs. These programs address the proliferation problem "at the source," striving to prevent the proliferation of weapons, weapons-usable materials, and WMD-related expertise. They consist of an integrated set of activities to secure at-risk nuclear material in Russia and the other states of the former Soviet Union, dispose of excess highly enriched uranium and plutonium, and assist in downsizing the Soviet-legacy nuclear weapons complex by helping Russia's closed cities and weapons institutes develop self-sustaining commercial applications of their scientific and technical expertise.

The Department of Homeland Security will serve to integrate and direct the nation's efforts to prevent terrorist attacks on the U.S., reduce the nation's vulnerability to terrorism, and manage the aftermath of any attack. Lawrence Livermore and the other

NNSA laboratories have unique scientific and technical capabilities that are directly applicable to homeland security. Indeed, Livermore-developed technologies are already being applied to a wide range of domestic national security issues, including critical infrastructure protection, law enforcement, and counterterrorism.

Other Important National Security Needs

Building on the scientific and technical capabilities needed for the Laboratory's stockpile stewardship and threat reduction missions, we develop advanced technologies for the Department of Defense (DoD) to enhance the effectiveness of U.S. military forces. We provide expertise in such areas as solid-state lasers, advanced conventional munitions, energetic materials, missile defense, counterproliferation planning, and conflict simulation.

Teamwork and Advances in Science and Technology

Collaborative Effort. Our work takes place within the context of the national security community—the three NNSA and other DOE laboratories, the production facilities and the Nevada Test Site, DoD, and the U.S. intelligence community. Many of our projects involve extensive collaborations with other national laboratories, government agencies, universities, and U.S. industry. We coordinate and integrate our efforts with others to provide the best scientific and technical capabilities to the nation as cost effectively as possible.

Internal Investments. We target Laboratory Directed Research and Development (LDRD) investments to enhance our ability to meet challenging, long-term national security priorities. These investments reinforce core Laboratory strengths, expand scientific

horizons, and create new technical capabilities. Nearly 94 percent of the Laboratory's LDRD projects in FY 2001 contributed directly to our national security mission. (Livermore's overall LDRD Program is discussed in Section 3.3.2.)

2.1 Stockpile Stewardship

The Stockpile Stewardship Program is designed to ensure the safety, security, and reliability of the U.S. nuclear weapons stockpile that is required to meet national security needs of the 21st century. The Office of Defense Programs within NNSA (NNSA/DP) is leading the three national security laboratories, the Nevada Test Site, and the production facilities that are part of the NNSA weapons complex in executing the program. Policy, planning, and implementation documents, including the *NNSA Strategic Plan* and Future-Year Nuclear Security Plan (FYNSP), provide direction for the Stockpile Stewardship Program.

Stockpile stewardship is a demanding program to meet a vital national interest. Confidence in the safety, security, and reliability of the weapons is to be maintained through an ongoing and integrated process of stockpile surveillance, assessment and certification, and refurbishment. The Stockpile Stewardship Program's ambitious goals include expeditiously putting in place a set of vastly improved scientific tools and manufacturing capabilities: 100-teraops supercomputers; advanced radiography capabilities to take three-dimensional images of imploding mock primaries; a high-energy-density and thermonuclear research facility; the National Ignition Facility, for studying the physics of weapons primaries and secondaries; and efficient, flexible, and

modern manufacturing facilities. Concurrently, the program must meet the current needs of DoD for direct stockpile support, which are growing as weapons continue to age.

Program Priorities and Activities at Livermore

Livermore's efforts support the *NNSA Strategic Plan's* Goal 1 and its two principal strategies that directly relate to stockpile stewardship:

Goal 1. Maintain and enhance the safety, security, and reliability of the nation's nuclear weapons stockpile to counter the threats of the 21st century.

Strategy: Conduct a program of warhead evaluation, maintenance, refurbishment, and production, planned in partnership with the Department of Defense.

Strategy: Develop science, design, engineering, testing, and manufacturing capabilities needed for long-term stewardship of the stockpile.

Success in long-term stewardship of the stockpile is also tied to Goal 4 in the *NNSA Strategic Plan* and its three strategies:

Goal 4. Ensure the vitality and readiness of the NNSA's nuclear security enterprise.

Strategy: Attract and retain the best laboratory and production workforce.

Strategy: Provide state-of-the-art facilities and infrastructure supported by advanced scientific and technical tools to meet operational and mission requirements.

Strategy: Protect classified information and assets.

To meet these goals, the Stockpile Stewardship Program is organized into three focus areas: Directed Stockpile Work, Campaigns, and Readiness in Technical Base and Facilities. These focus areas provide an organizational

structure for Livermore's stockpile stewardship activities and the subsequent discussion of them. Priorities for these activities are established through consideration of integrated program goals—both priorities described in stockpile stewardship policy, planning, and implementation documents and risks to the overall program if specific activities are less than fully supported.

Livermore's integrated priorities, highest first, are to:

- **Keep the current stockpile safe, secure, and reliable.** This effort involves projects such as the W87 and W80 Life-Extension Programs (LEPs), surveillance, and baselining of the current stockpile systems to support Annual Certification and the planning for future LEPs. These activities make full use of advanced computing capabilities and simulation tools, physical databases, and experiments at the NNSA weapons complex's current suite of facilities.
- **Accelerate development and use of the advanced experimental and computational capabilities** needed to resolve complex stockpile issues. Major activities include Laboratory, industry, and university efforts in high-performance computing platforms and applications (ASCI), construction and commissioning of the National Ignition Facility, and development and application of advanced radiography technologies and facilities that conduct high-explosive experiments on mock weapon primaries.
- **Further develop the underlying science and technology** critical to future stockpile assessment and certification. To understand the performance and aging characteristics of nuclear weapons, we need state-of-the-art theory, modeling, and experiments on materials and detailed atomic and nuclear processes.

• **Develop production technologies** for use when the current stockpiled systems must be refurbished or replaced.

Our success in meeting these priorities—particularly in the long term—depends on continuing to attract high-quality personnel in the program. Hence, an overarching Laboratory priority is to:

- **Retain, recruit, and develop the skills of the technical staff** required to execute the Stockpile Stewardship Program at the Laboratory.

The Growing Challenge

Significant challenges lie ahead because the demands on the program will grow as weapons in the enduring stockpile continue to age. Weapons in the U.S. nuclear stockpile are now older on average than they have ever been. Stockpile problems must be anticipated or detected and then evaluated and resolved without nuclear testing. Existing warheads and weapon systems will have to be refurbished to extend stockpile lifetimes and to meet future military requirements. We also must be responsive to new requirements and prepared to deal with surprises. At the same time, the reservoir of nuclear test and design experience at the laboratories continues to diminish as staff members retire. This experience base—and the emerging new tools needed to resolve stockpile issues—must be passed on to the next generation of stockpile stewards.

Successful execution of Livermore's program responsibilities presents many technical and management challenges. The technical demands of the program are significant—many aspects of the required science and technology are at the leading edge of what is possible. Stockpile stewardship requires major investments in new facilities and capabilities to make it possible for

scientists and engineers to understand ever more thoroughly the performance of nuclear weapons. The program will not succeed without the new facility investments that NNSA is making. At the same time, scheduled programmatic work at the laboratories and plants to meet DoD requirements is also placing exceedingly high demands on the provided funding. In addition, funds are needed to recapitalize NNSA's underlying infrastructure. Management challenges stem from the need to both integrate and balance these elements of the program while working within tight budget constraints.

Managers are also responsible for ensuring that expertise remains high in all aspects of nuclear weapon science and engineering, with particular attention to workforce recruiting, effective on-the-job training, and retention of highly qualified scientific and technical personnel. Workforce recruiting and development are high priorities at the Laboratory (Section 4.3). Both recruiting and retention of top-quality staff benefit from the Laboratory's LDRD Program (Section 3.3.2) and various ties to universities (Section 3.4.3). These efforts, together with the Science and Technology Education Program (Section 3.4.4), help to attract high-caliber scientists and engineers and develop a future workforce to work on challenging national security problems.

2.1.1 Integrated Program Management and Implementation

Situation and Issues

Integrated program management and implementation are critical to the success of the Stockpile Stewardship Program. The major program elements are tightly interconnected, as are the activities of the three laboratories, the

Nevada Test Site, and facilities at Kansas City, Pantex, Savannah River, and Y-12. Policy, planning, and implementation documents developed by NNSA specify roles and responsibilities within the program and define the capabilities needed for stockpile stewardship without nuclear testing. The plans integrate surveillance, assessment, life-extension design, and manufacturing activities for each weapon system. Program integration efforts also include formal processes with DoD for coordinating assessments of stockpile performance and modifications.

Program Thrusts

NNSA's Long-Term Planning and Budgeting. NNSA is taking a number of actions to enhance performance and improve processes for long-term planning and budgeting, which are critically important to the development and execution of a balanced Stockpile Stewardship Program. One key change is the development each year of the Future-Year Nuclear Security Plan (FYNSP). With this five-year plan, NNSA is better able to make program trade-offs, which involve adjustments to future-year budgets, and the FYNSP helps Livermore in resource, workload, and facility planning by providing a more reliable future program base than existed previously.

Annual Assessment and Certification Actions. Livermore is a key participant in formal review processes and assessments of weapon safety, security, and reliability. Annual Certification of the stockpile for the President (now called the Annual Assessment Review) is a formal process that is based on technical evaluations made by the laboratories and on advice from the three laboratory directors, the commander-in-chief of the Strategic Command, and the Nuclear Weapons Council. To prepare

for this process, we collect, review, and integrate all available information about each stockpile weapon system, including physics, engineering, chemistry, and materials science data. This work is subjected to rigorous, in-depth intralaboratory review and to expert external review. The sixth annual assessment cycle was completed in 2001.

For the Annual Assessment Review—and the formal certification required for modified units of previously certified and tested weapons—we are depending on a much more extensive range of aboveground testing, together with a vastly improved simulation capability. The existing nuclear test database is a crucial resource for challenging the validity of these improved codes. We have also begun to use a rigorous set of quantitative standards as the basis for formal certification actions and are beginning to apply them in the Annual Assessment process. The methodology used in this process, quantification of margins and uncertainties (QMU), is discussed in Section 2.1.2. QMU can also help provide prioritization for the Laboratory's technical efforts and for the overall Stockpile Stewardship Program, for example, by helping us determine where to invest in capabilities to raise confidence in weapon performance. That is, QMU can help provide direction for the efforts to improve weapon surveillance and for the science and engineering campaigns, discussed below.

Program Alignment and Integration.

For the Stockpile Stewardship Program to succeed, it is crucial that the activities at all NNSA sites be a unified effort with integrated goals, milestones, and schedules. To this end, the program is formally managed through three overarching sets of activities: Directed Stockpile Work, Campaigns, and Readiness in Technical Base and

Facilities. NNSA/DP uses this breakout to make evident program integration, establish clear goals and budget priorities, and help to identify risks if there are budget shortfalls. The integrated program activities include:

- **Directed Stockpile Work.** Directed Stockpile Work supports the readiness of weapons and includes activities to meet current stockpile requirements.

- **Campaigns.** Campaigns are directed at making the scientific and technological advances necessary to assess and certify weapon performance now and over the long term without nuclear testing.

- **Readiness in Technical Base and Facilities.** Readiness in Technical Base and Facilities ensures that necessary investments are made to conduct the program today and to have in place the needed capabilities as more challenging stockpile issues arise in the future. Readiness includes the fixed costs and the investments of the Stockpile Stewardship Program.

In conjunction with this approach to managing activities, a rigorous planning process has been established to clearly define programmatic milestones to be achieved within each program element. The Stockpile Stewardship Program is defined by the Future-Year Nuclear Security Plan together with a series of five-year plans, one for each element, describing goals and objectives. The five-year plans—developed with the participation of the laboratories, plants, and test sites—are accompanied by annual implementation plans with detailed milestones.

2.1.2 Directed Stockpile Work

Directed Stockpile Work supports the readiness of weapons. It includes weapon maintenance, comprehensive surveillance, weapon baselining,

assessment and certification, supporting research and development, and scheduled weapon refurbishments. The effort also includes other stockpile commitments, such as dismantlement and information archiving.

Situation and Issues

Stockpile Requirements. On an annual basis, the President issues the Nuclear Weapons Stockpile Plan, which is prepared by the Nuclear Weapons Council and reviewed by the NNSA administration and Secretaries of Defense and Energy. The plan sets the requirement to maintain a safe and reliable nuclear weapons stockpile. It specifies the number of weapons of each type to be in the stockpile and, hence, which nuclear weapons systems are available for dismantlement. Among its other responsibilities, DoD establishes military requirements, which are incorporated into the President's plan. These requirements drive the Directed Stockpile Work for NNSA, particularly in the resource-intensive area of refurbishment activities and LEPs.

Livermore-Designed Weapons and Responsibilities. Livermore is the design laboratory for four nuclear weapon systems in the stockpile: the W87 and W62 ICBM warheads, the B83 bomb, and the W84 cruise missile warhead. These systems are expected to remain in the stockpile well past their originally anticipated lifetimes; the W62 is already doing that. The Laboratory has special responsibilities for these systems, including surveillance, performance and safety assessments, and refurbishment. In addition, Livermore has broader responsibilities to develop assessment capabilities, technologies, and processes that contribute to maintaining the safety, security, and reliability of all stockpiled weapons.

Assessments. Assessments provide the foundation for formal certification of stockpile performance and for refurbishment decisions. Assessments must be based on scientific and engineering demonstrations to be credible. In the absence of nuclear testing, we rely on data from past nuclear tests as a benchmark, component-level experiments and demonstrations, and advanced simulations for an integrated assessment of weapon performance and safety.

The Stockpile Stewardship Program includes a comprehensive set of assessment activities to address issues that arise from stockpile surveillance and to evaluate the significance of observed and predicted aging processes. When modifications are deemed necessary, we must assess options for refurbishing or replacing specific warhead components as well as options for new production and fabrication processes and materials. Modification actions must then be certified.

Stockpile Surveillance. Our stockpile surveillance activities focus on Livermore designs in the stockpile. These efforts include developing improved monitoring capabilities and building the scientific base to better understand aging effects in all stockpiled weapons (see Enhanced Surveillance Campaign in Section 2.1.3). With an improved understanding of aging, we can better predict changes in the stockpile and conduct systematic refurbishment and preventive maintenance activities to correct developing problems. We also perform surveillance testing of the detonator systems on the Livermore-designed weapons. In addition, pits from Livermore-designed weapons are now being thoroughly examined at facilities in the Superblock—a new mission for

Livermore. These pit surveillance activities previously had been conducted at Los Alamos.

Weapon Refurbishment. Weapon refurbishment through life-extension programs is needed because weapon components degrade over time. Refurbishment is a particularly demanding challenge because we cannot rebuild many weapons components exactly as they were manufactured. In many cases, the materials or the manufacturing processes originally used are no longer available or are environmentally unacceptable.

Livermore's first LEP, refurbishment of the W87 ICBM warhead, is in its production phase. Certification of the W87 refurbishment was completed in April 2001. This first completed certification of the engineering design and production processes for an LEP is a landmark accomplishment for the Stockpile Stewardship Program.

Lawrence Livermore and Sandia/California have been assigned responsibility for the program to extend the life of the W80 cruise missile warhead. This assignment better balances the workload among the laboratories and provides a vehicle for the Laboratory to develop the skills of the next generation of stockpile stewards.

Activities to improve the manufacturing of weapons components are part of LEPs as well as the Advanced Design and Production Technologies (ADaPT) Campaign discussed in Section 2.1.3. We are working closely with the production plants to integrate the development of replacement components with the development of new materials and manufacturing processes. By making use of modern production technologies and incorporating major technical advances that have occurred since the weapons were first

manufactured, we can lower the cost of weapon refurbishment and reduce the environmental impact of the processes.

Program Thrusts

A Strategy to Improve Assessment

Capabilities. The expectation that more challenging stockpile issues will arise as weapons continue to age is driving the program's campaign strategy (see Section 2.1.3) and investments in more capable experimental facilities (see Section 2.1.4). These investments include the National Ignition Facility (NIF) and the Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility at Los Alamos. We are also developing greatly enhanced numerical simulation tools through the Advanced Simulation and Computing (ASCI) Program. Livermore has major responsibilities in the execution of ASCI and the construction, commissioning, and operation of NIF.

Quantification of Margins and

Uncertainties. For certification actions, it is essential that we use a rigorous set of quantitative standards that are technically sound (to bolster our confidence) and provide transparency to the government and military (to build their trust and confidence in us). The methodology now being used in this process is called the quantification of margins and uncertainties (QMU). Livermore first applied the QMU methodology to certification of the W87 LEP. It is being further developed and jointly implemented by Livermore and Los Alamos as a single national certification process.

QMU standards are based on ensuring that adequate margins exist against limited uncertainties for each sensible way that the warhead can fail to function properly (analogous to the engineering safety factors used in

building a bridge). Margins must be adequate whether the concerns are driven by aging, remanufacturing, possible design or manufacturing flaws, or new requirements for warheads.

For each issue, we gather data and conduct simulations to first determine how close we are to the margin of failure and then estimate uncertainties. This process entails the efforts of many experts, extensive peer group review, and careful scrutiny by "red teams." The outcome is a set of quantitative confidence factors that can be used as a basis for judgments. QMU can also help in prioritizing the Laboratory's technical efforts and the overall Stockpile Stewardship Program.

W87 Life Extension. The W87 LEP Final Development Report was signed by the directors of Livermore and Sandia national laboratories in April 2001, and the W87 Alt 342 was accepted as a Standard Stockpile Item on November 28, 2001. The LEP enhances the integrity of the warhead so that it can remain part of the enduring stockpile beyond the year 2025 and will meet anticipated future requirements for the system. The development activities included extensive flight testing, ground testing, and physics and engineering analysis.

This successful LEP establishes a rigorous benchmark for the Stockpile Stewardship Program, and it demonstrates the ability of the NNSA laboratories and production facilities working together to overcome physics, engineering, and manufacturing challenges to meet DoD requirements. As of mid-2002, the W87 LEP production is more than 50 percent complete. Production is on schedule, with the final unit scheduled for completion in 2004. The Laboratory continues its collaboration with the

production plants, working to ensure the quality of the W87 refurbishment work while maintaining the targeted production rate.

W80 Life Extension. Under the direction of the Nuclear Weapons Council, the W80 Project Officers Group (POG) is pursuing an LEP for the W80 cruise missile warhead. A formal study that defined refurbishment options and their feasibility (known as a 6.2 study) was completed in 2000. Livermore and Sandia/California participated as an Interlaboratory Peer Review team. Although the W80 was originally developed by Los Alamos and Sandia/New Mexico, NNSA assigned the associated engineering development task for the LEP to Livermore and Sandia/California.

Working closely together, the New Mexico and California teams established a modern baseline understanding of the W80 and its performance. The baselining project, which was completed in September 2001, included sharing information about the W80 with the transfer of over 2,800 electronic files between Livermore and Los Alamos, new analysis and study efforts at each of the laboratories, and two two-day baselining workshops to share information and critique work. By January 2002, a comprehensive report (*The W80 Baselining Report*) was published and distributed.

Substantial test activities were initiated in the first half of FY 2002. The current schedule calls for the first production unit of the refurbished warheads in FY 2006. Livermore will be responsible for continuing evaluations of their performance. Los Alamos will retain this responsibility for W80s not yet refurbished.

Improved Surveillance of the Stockpile. Using the experience and

data we have gathered, we continually review and upgrade our surveillance programs—refining sampling plans, measuring additional attributes, introducing new diagnostic tools, and improving analysis methods. We also have assumed responsibility for surveillance of pits from Livermore-designed weapons in the stockpile to better balance the workload among the laboratories. These pit surveillance activities had been conducted at Los Alamos. In FY 2001, we successfully demonstrated the capability to perform pit surveillance at the Plutonium Facility at Livermore by carrying out the necessary operations on a Livermore-designed pit.

In addition, as our contribution to the Enhanced Surveillance Campaign (see Section 2.1.3), we develop processes and deploy newly emerging diagnostics into the core surveillance program. These diagnostics are enabling us to better diagnose and quantify the condition of the stockpile and to identify aging characteristics at the earliest possible time. For example, Livermore, in cooperation with Y-12, has completed the development of an analytical model and the development and deployment of a suite of diagnostic tools that enable us to understand the aging behavior of secondary assemblies. We are completing a high-resolution x-ray tomography system for imaging weapon pits. First-phase deployment at Livermore is complete, and the system has been demonstrated. Deployment at Pantex is continuing. Furthermore, high-energy neutron radiography continues to be improved for nondestructively detecting small voids and structural defects in weapon systems.

Improved Production Technologies. We are contributing to the development

of SecureNet, a complex-wide, secure, high-speed digital network to share classified information on a need-to-know basis. The system is enabling Livermore engineers and designers to have access to “as-built” production, disassembly, and surveillance data from Y-12 and Pantex during W87 LEP activities. The Weapons Technical Data Exchange project, which we are pursuing as part of the advanced design and production technologies campaign (ADaPT, discussed in 2.1.3), is also supporting the W80 LEP by facilitating the transfer of data for the W80 warhead system between Los Alamos, which designed the W80, and Livermore, which is responsible for the LEP. We are also implementing the Weapons Information Management System (WIMS) to effectively and efficiently store, manage, and retrieve information in support of LEP design and production activities and surveillance.

Other information and manufacturing technologies are being pursued as part of Livermore’s contribution to the ADaPT campaign in projects designed to support plans and needs for stockpile LEPs. Activities range from the development of precision die-casting technologies for pit production and tomographic diagnostic techniques for electron-beam welding to new methods for production of TATB (an insensitive high explosive) and the synthesis and characterization of a new insensitive high explosive (LLM105).

Directed Stockpile Workload Planning. Building on the success of the W87 LEP, we are developing comprehensive plans to extend the stockpile life of other Livermore-designed systems. To this end, significant effort is being expended on their surveillance, maintenance, and selective refurbishment.

DOE and DoD must work together effectively to refine plans—including budgets and schedules—for future refurbishment activities for each system in the enduring stockpile. We need to develop a range of realistic, well-defined options that then must be weighed according to risks and benefits. Balancing benefits and risks in a highly constrained budget environment will be difficult. Near-term affordability issues—together with the prospect of better definition of which components should be replaced and the possibility for improved design options—argue for tackling the more challenging refurbishment actions later if they are not yet necessary. However, that decision could lead to later workload balancing issues at the plants. It would also increase the burden on future stockpile stewards, who will face the more challenging issues without the experience base of the current staff.

2.1.3 Stockpile Stewardship Campaigns

Situation and Issues

The Stockpile Stewardship Program Campaigns are directed at making the scientific and technological advances necessary to assess and certify nuclear weapon performance now and over the long term. They integrate experiments, simulation development, and assessment activities and focus on achieving specific needed capabilities. Seventeen campaigns are being pursued. As they progress, the campaigns will achieve scheduled interim objectives relevant to stockpile needs. For each campaign, the resource needs have been determined together with an assessment of program risks if funding is not adequate. In addition, a set of cross connections with other elements of the program has been identified.

Significant Accomplishments. In FY 2001 and FY 2002, Livermore achieved a number of significant accomplishments in its campaign activities, such as:

- The three-dimensional (3D) simulation of a full-system nuclear weapon explosion, from primary implosion to secondary explosion. The simulation ran a total of 43 days on 1,024 processors of the ASCI White computer and produced tens of terabytes of data.
- Completion of the Oboe subcritical experiments, which used confinement vessels for rapid turnaround of test results. Over the series of nine experiments, significant progress has been made on our understanding of phenomena associated with shocked plutonium, including successful tests of theory.
- Progress in understanding the aging of key materials in weapons through a variety of experiments and modeling efforts. Notably, the Laboratory has completed installation of a unique suite of special tools for metallurgical and chemical examination of plutonium and continues to develop experimentally benchmarked models of canned sub-assemblies.
- Major improvements to the scientific rigor of the detonation kinetics in the CHEETAH code. By adding a link to a hydrodynamics code, we have the capability for explosive equation-of-state and kinetic properties to be calculated as the material configuration changes.
- Use of the three-dimensional HYDRA code to simulate the performance of targets being designed to achieve ignition and thermonuclear burn in NIF. Continuing experiments on the Omega laser examine physics issues and aid in the planning of NIF experiments.
- Continuing improvements through the Nuclear Weapons Information Project (NWIP), which is revolutionizing the

way researchers access weapons data and information, setting a complex-wide standard for information exchange and use.

These and other accomplishments are described in detail in Livermore's *Annual Report, Science & Technology Review* (the Laboratory's monthly publication), and *National Security Review* (the Laboratory's classified journal).

Program Thrusts

The current set of 17 campaigns is briefly described. Teams across the DOE weapons complex work together to focus and optimize their combined resources to achieve overall milestones and end states. Livermore's role in each campaign varies, and our major contributions are highlighted in Table 2-1.

In general, we are primarily focused on the eight campaigns to improve the scientific understanding of weapons performance. We also work in close partnership with the production facilities on the four applied-science and weapons-engineering campaigns, and in selected areas, we provide development support to the five campaigns to sustain the manufacturing base.

Eight campaigns are aimed at providing the scientific understanding needed to certify the nuclear weapons stockpile in the absence of nuclear testing and to support required weapon modernization in LEPs. The additional campaigns focus on applied science and weapons engineering. They provide specific tools, capabilities, and components to support weapon maintenance, modernization, and refurbishment as well as certification of weapon systems. The 17 campaigns we support are:

1. Primary Certification Campaign.

This campaign focuses on developing and implementing the tools required to certify the performance and safety of

any rebuilt or aged primary. Primary performance must be understood within a certain margin of error, and the QMU methodology will provide the basis for quantitative standards to ensure that adequate performance margins exist (also see QMU discussion in Section 2.1.2). Among the many activities supporting this campaign are efforts to develop validated models of high-explosives denotation, boost physics, and primary burn.

2. Dynamic Materials Properties

Campaign. The goal of this campaign is to acquire data and develop accurate, experimentally validated models that describe the behavior of materials at the level of accuracy needed for certification of weapon performance. One area of special emphasis is determination of the equation of state and constitutive properties of plutonium (e.g., strength, spall, ejecta) as well as organic materials and deuterium–tritium gas mixtures.

3. Advanced Radiography Campaign.

This campaign aims to provide three-dimensional dynamic radiographic images of imploding surrogate primaries as well as associated analytical capability applicable to the certification of rebuilt primaries. After nuclear testing, advanced radiography is the most important experimental tool that we have to maintain an aging nuclear stockpile. This campaign includes completing and operating the DARHT Facility, developing advanced simulation and analysis capabilities, and providing a technical basis for deciding the next step on the path to more advanced radiography capabilities.

4. Secondary Certification and Nuclear Systems Margins Campaign.

This campaign examines the performance of secondaries to identify the minimum factors necessary to produce a militarily effective weapon. The objectives of this campaign include

Table 2-1. Livermore contributions to the DOE Defense Program Campaigns.

Campaign	Major Livermore Technical Efforts
1. Primary Certification	High-fidelity modeling and experiments: with plutonium at NTS (JASPER gas gun and subcriticals), high explosives at the High-Explosives Applications Facility (HEAF) and Site 300, hydrotests at the Flash X-Ray/Contained Firing Facility and DARHT; calculational model development.
2. Dynamic Materials Properties	Subcritical and JASPER gas-gun experiments (Pu); high-explosives experiments at HEAF and Site 300; Z-machine and diamond anvil cell equation-of-state experiments; calculational model development.
3. Advanced Radiography	Technical support for LANL proton radiography development, linear induction accelerator (LIA) work for DARHT-2; LIA advanced technology development; lead for containment; materials research.
4. Secondary Certification & Nuclear Systems Margins	Case configuration experiments at Site 300; opacity, transport, and interaction experiments using the Omega Laser; diagnostics and target development for Omega and NIF; physics model development.
5. Enhanced Surety	Development of advanced initiation, safing, optical, and high-explosives technologies.
6. Weapon System Engineering Certification	Experiments to validate models; system-level confirmatory experiments.
7. Nuclear Survivability	Nuclear weapon outputs and environments; weapon vulnerability and hardness, including experiments at Omega and NIF.
8. Enhanced Surveillance	Complementary experimental and modeling efforts: aging (and accelerated aging) of pits, canned subassemblies, and high explosives; acquisition of improved tools to study plutonium.
9. Advanced Design & Production Technologies	Development of materials and production process technologies for enterprise integration (<i>SecureNet</i>), agile manufacturing, and environmentally benign production.
10. ICF Ignition & High Yield	NIF construction and operation; target design and fabrication; experiments and diagnostics.
11. Advanced Simulation & Computing	ASCI applications development; data visualization; platform integration; validation and verification; improved materials properties models.
12. Pit Manufacturing & Certification	Manufacturing and certification of W88 pits; plans for design and construction of a Modern Pit Facility; reestablishment of capability to make all types of stockpile pits.
Five Production Readiness Campaigns	Development of production processes.

(1) developing a validated predictive computational capability for each system in the stockpile; (2) quantifying, through simulation and experiments, our understanding of primary radiation emission and energy flow; and (3) determining the performance of

nominal, aged, and rebuilt secondaries. The data gathered through this campaign and application of the QMU methodology (see Section 2.1.2) will enable scientists to develop a more rigorous predictive capability and ensure that “margins” necessary for the

performance of secondaries are adequate. **5. Enhanced Surety Campaign.** The goal of this campaign is to increase nuclear safety and security. Main efforts include developing advanced capabilities in micro, optical, and solid-state technologies to improve nuclear warhead

safety as well as enhancing use-control and use-denial technologies. A critical factor is to qualify surety solutions for planned stockpile life-extension refurbishment activities while maintaining flexibility to respond to surprises encountered during refurbishment.

6. Weapon System Engineering Certification Campaign. The intent of this campaign is to establish engineering certification methods that quantify performance and uncertainties of weapon systems at a reduced cost. Predictive engineering computational models for stockpile LEP activities will be developed and validated through fewer, smarter, system-level confirmatory experiments. The goal is to greatly increase the information gained from each fielded experiment so that we can increase weapons understanding while we reduce the number of tests and associated costs.

7. Nuclear Survivability Campaign. The goal of this campaign is to develop certification tools and microelectronics technologies to ensure that refurbished weapons meet stockpile-to-target-sequence (STS) requirements for hostile environments. Technical objectives include developing a suite of validated computational tools for nuclear survivability and vulnerability design and certification using nuclear environments generated with pulsed-power and laser-based facilities, reevaluating nuclear-weapon hostile environments, and demonstrating certification technologies on the W76 LEP. The development of computational models will reduce reliance on laboratory tests.

8. Enhanced Surveillance Campaign. This campaign will provide a validated basis to certify aged components, specify when components must be replaced, and determine when new

manufacturing facilities are needed. It will provide the first science-based assessment of the lifetimes of pits, high explosives, organic materials, and canned secondary subassemblies and furnish quantitative bases for future stockpile life-extension activities. One of the goals is to minimize or eliminate unnecessary refurbishment costs.

9. Advanced Design and Production Technologies (ADaPT) Campaign.

This campaign aims to develop improved modeling and simulation tools and information management technologies so that refurbishment products are high in quality and are delivered cheaply and quickly. The campaign will enable full-scale engineering development for weapon component refurbishment with minimal hardware prototyping and paperless monitoring of production activities.

10. Inertial Confinement Fusion (ICF) Ignition and High-Yield Campaign.

This campaign is directed at improving our understanding of phenomena at star-like temperatures that govern the performance of thermonuclear weapons. The performance of experiments at high-energy-density research facilities is central to the campaign, and construction of NIF is essential for overall success. Material conditions that can be reached in NIF, together with the diagnostics available, will allow the experimental study of thermonuclear burn and important regimes of high-energy-density science. The long-term goal of this campaign is to achieve ICF ignition implosions in NIF.

11. Advanced Simulation and Computing Campaign. This campaign focuses on the shift from nuclear-test-based methods to computation-based methods to certify the safety, reliability, and security of the stockpile. The capabilities coming online through ASCI

make possible three-dimensional, high-fidelity, full-system simulations. The goal is to develop the simulation software required for engineering, safety, and performance analyses of weapons in the stockpile.

12. Pit Manufacturing and Certification Campaign. The long-term goal of this campaign is to reconstitute pit manufacturing within the DOE nuclear weapons complex for all pit types. Specific tasks include the establishment of a W88 pit production capability at a limited (10 pits per year) level, certification of pits made with the new processes, and planning for a Modern Pit Facility.

The final five campaigns support readiness by focusing on sustaining the manufacturing base within the weapons complex.

13. Secondary Readiness Campaign. This campaign will ensure that future manufacturing capabilities are in place, including the reestablishment of special materials processing, replacement of antiquated technologies, maintenance of workforce competencies, and development of component certification and recertification techniques for weapon secondaries.

14. High-Explosives (HE) Manufacturing and Weapon Assembly/Disassembly Readiness Campaign. This campaign is focused on ensuring future manufacturing capabilities for high-explosives fabrication and weapon assembly.

15. Nonnuclear Readiness Campaign. This campaign will ensure that future manufacturing capabilities for nonnuclear components are available.

16. Materials Readiness Campaign. This campaign includes activities to support the construction of a new highly enriched uranium (HEU) storage facility at Y-12.

17. Tritium Readiness Campaign. The focus of this campaign is to develop a source of tritium for meeting future stockpile needs. A commercial light-water reactor is the primary technology option under consideration, with a linear accelerator (linac) option as a backup.

2.1.4 Readiness in Technical Base and Facilities

Readiness in Technical Base and Facilities calls for investments in people and their supporting infrastructure to conduct the program today and to have in place the needed capabilities as more challenging stockpile issues arise in the future. The Stockpile Stewardship Program's success depends on the presence of well-trained, motivated people together with a well-maintained, modern infrastructure that is operated in a safe, secure, and environmentally responsible manner.

Success also requires bringing online the experimental and computational facilities that are especially needed in the absence of nuclear testing. Because they are not formally part of the Readiness in Technical Base and Facilities element of the Stockpile Stewardship Program, the Laboratory's major activities in NIF and ASCI are discussed in Sections 2.1.5 and 2.1.6.

Situation and Issues

We face the absolutely crucial challenge of maintaining expert judgment about nuclear weapons issues. That challenge has been recognized from the onset of the Stockpile Stewardship Program. It was carefully considered by the Commission on Maintaining United States Nuclear Weapons Expertise ("Chiles Commission") and more recently by the Foster Panel and the National Commission on Science and

Security ("Hamre Commission"). These panels correctly pointed out the need at the laboratories for a sustained recruiting and training effort to supplement our veteran workforce.

Retirement age is nearing for a significant fraction of the Laboratory's career workforce with "critical skills" that support the Stockpile Stewardship Program and related activities. More than 40 percent of Defense Programs-funded engineers, scientists, technicians, and their managers are over 50 years old. Less than 20 percent of the "critical skills" career-employee population at Livermore is 40 years old or younger. Retention of the current staff and recruitment and training of new scientists, engineers, and technicians are vitally important for the continuing health of the Stockpile Stewardship Program. The good news is that this past year has been a very good one for recruiting new technical talent to Livermore, with a large number of applicants and the return of some who had left the Laboratory for private industry several years ago.

Key Stockpile Research Facilities at Livermore. Livermore has special responsibilities in the Stockpile Stewardship Program because of our particular skills and capabilities and because unique user facilities at Livermore must be maintained. In addition to a number of important but smaller science and engineering facilities, these include:

- The High-Explosives Applications Facility (HEAF). The most modern facility for high-explosives research in the world, HEAF is a center for the study of chemical high explosives. It combines all the capabilities needed to synthesize, formulate, and test new explosive compounds. High explosives can be safely detonated in specially

designed vessels in quantities up to 10 kilograms. Experiments are supported by state-of-the-art diagnostic equipment that includes high-speed, rotating-mirror streaking and framing cameras, electronic image-converter cameras, optical interference velocimeters, and image-forming x-ray machines.

- The Flash X-Ray/Contained Firing Facility at Site 300. This modern hydrodynamic test facility is capable of conducting "core punch" experiments that record a detailed digital image of a mock weapon primary when it is highly compressed. The Flash X-Ray Facility has been upgraded to contain the debris created by explosive testing through the construction of the Contained Firing Facility (CFF). Dedicated in April 2001, the CFF has completed qualification testing to assure its ability to contain debris from experiments that use up to 60 kilograms of high explosives. Testing has resumed; however, a return to full testing capability has been delayed by the need to make modifications to meet extremely stringent standards for beryllium cleanup, which were recently imposed by DOE.

- The Secure and Open Computing Facilities. These facilities assist our programs and serve as a testbed for development of high-performance computing hardware and software. Livermore Computing maintains two computing facilities, one for classified work (the Secure Computing Facility) and the other for unclassified work (the Facility for Advanced Scalable Computing Technology).

- The Superblock. Housing modern facilities for special nuclear materials research and engineering testing, the Plutonium Facility, in particular, is engaged in activities to prepare and monitor accelerated-aging plutonium samples. The facility is also used to

prepare plutonium samples for Livermore's subcritical tests, to investigate technologies for the remanufacture of plutonium parts in Livermore-designed weapons, and to conduct other fundamental physics and engineering experiments using plutonium. In addition, pit surveillance of Livermore-developed weapons is now being conducted at the facility.

- **JASPER.** Livermore constructed and is responsible for operation of the Joint Actinide Shock Physics Experimental Research (JASPER) Facility at the Nevada Test Site. JASPER's two-stage gas gun performs shock tests on special nuclear materials. The facility is designed for the use of uranium and plutonium targets. JASPER experiments will complement other experimental and modeling activities by providing scientists more precise equation-of-state data at extreme conditions than can be obtained from other types of experiments.

The Need for Infrastructure Reinvestment. We strive for a work environment at Livermore that attracts top-notch employees, enhances workforce productivity, and helps ensure programmatic success. This requires modern facilities at the Laboratory. A core strength of Livermore is its unique, state-of-the-art research facilities, but we also have many aging facilities.

As discussed in Section 4.4, overall, 11 percent of Livermore's office and laboratory space is in need of major rehabilitation and nearly 30 percent of the space is in need of minor rehabilitation. Older facilities typically are more expensive to maintain and usually have higher costs associated with safe and healthy operations. Our overall maintenance backlog is about \$235 million if funded with programmatic dollars. In addition, obsolete equipment needs to be replaced.

The Laboratory also has legacy facilities from long-discontinued programs as well as outdated and unusable laboratory space that must be decommissioned, decontaminated (where necessary), and demolished. Finally, we have to invest so that buildings at Livermore meet present-day codes and the latest, more demanding seismic safety criteria.

Program Thrusts

The Laboratory's future workforce and facilities are areas of considerable attention. The steps we are taking in workforce recruitment and retention are discussed in Section 4.3. Some of our activities that particularly pertain to recruiting are highlighted below, as are two major construction items. Section 4.4 presents a comprehensive summary of Livermore's facility plans and resource requirements.

Recruitment for Defense Programs Activities. New employees recruited into Livermore directorates that support stockpile stewardship come from a number of sources, all of which require Laboratory outreach, particularly to academic institutions. Recruitment measures include on-campus recruiting, relationships established through collaborative research activities, postdoctoral fellowship programs at the Laboratory, contacts made at professional scientific and engineering society meetings, advertisements in professional journals, and position postings on the World Wide Web. In particular, Livermore benefits from Defense Programs' Laboratory Critical Skills Development Program, which directly provides matching funds to support many interns who work on stockpile stewardship projects (see Section 3.4.4). In addition, through a variety of activities, we have developed a wide range of academic collaborations

on physics and computational topics relevant to the needs of the Stockpile Stewardship Program. Two prominent examples are the University of California Research Institutes (five of which are located at Livermore, as discussed in Section 3.4.3) and the Academic Strategic Alliances Program (ASAP), which is part of ASCI. These academic alliances are discussed in Section 2.1.6. Many other Laboratory-wide efforts to bolster workforce recruiting, continuing education, and retention are discussed in Section 4.3.

Infrastructure Reinvestment. As discussed in Section 4.4, through the use of the prioritization methods and innovative rehabilitation and decontamination and demolition (D&D) processes we have piloted, the Laboratory has in place effective means for managing its infrastructure—but we do not have enough funding to make headway at reducing accumulated problems. Accordingly, our input into NNSA/DP's Infrastructure Re-Capitalization Program for FY 2003 includes over \$36 million for high-priority items. Some high-priority items include roof and ductwork replacement, seismic upgrade work, backlog reductions and upgrades, road repairs and rerouting, building renovation, demolition of two buildings, and investments in high-efficiency particulate air (HEPA) filters to more effectively ensure that our high environmental standards continue to be met.

2.1.5 The National Ignition Facility

The National Ignition Facility (NIF), currently under construction at Livermore, will be a 192-laser-beam facility capable of achieving fusion ignition and energy gain in the laboratory for the first time. The NIF laser system provides a total energy of

1.8 megajoules of ultraviolet laser light directed into a 10-meter-diameter target chamber. The NIF facility consists of the laser and target area building, nearly 300,000 square feet in size, with adjacent support facilities for cleaning, assembling, and refurbishing the optical and optomechanical components of the laser, target diagnostics, and experimental support and a number of test facilities for integrated systems development, prototyping, and qualification.

NIF benefits from the extensive experience gained at Livermore using a series of large lasers built over the past 30 years. NIF will deliver 60 times more energy than the Nova laser, which was built and operated at the Laboratory between 1984 and 1998. Many of the key technical features of NIF were tested using the Beamlet laser at Livermore, which operated between 1994 and 1998. Features included the multi-pass amplifiers; large-aperture optical switches; large frequency-conversion crystals; deformable mirrors for adaptive optical correction of laser beam wavefront; power conditioning, capacitor, and flashlamp systems; and high-fluence, large-area optics.

Situation and Issues

The Need for NIF. NIF will support national security, energy, and scientific goals. A critical element of the Stockpile Stewardship Program, NIF is designed to ensure the reliability of the country's remaining nuclear weapons without full-scale nuclear testing. It is the only facility in the program that can achieve fusion ignition and obtain temperatures and pressures approaching those in an exploding nuclear weapon. Experiments on NIF will also evaluate the scientific feasibility of inertial fusion energy, which has been a long-standing program

goal within DOE. In addition, NIF will provide nuclear environments for studying weapons effects and will allow laboratory astrophysics and basic science studies under conditions similar to those found in stars.

NIF is needed for experimental study of key issues related to the effects of aging on weapons and to aid in the certification of refurbished weapon systems. In addition, NIF experiments provide the only available means for advancing our understanding of certain critical aspects of the underlying science of nuclear weapons. NIF experiments will provide necessary data for sophisticated computer simulation models being developed for stockpile stewardship. The models themselves must be benchmarked and validated using the physical conditions that only NIF can provide. Finally, NIF will help to attract and train the exceptional scientific and technical talent that is required to sustain the Stockpile Stewardship Program over the long term.

NIF's essential role in the Stockpile Stewardship Program was reconfirmed by the findings of NNSA/DP's High-Energy-Density Physics (HEDP) Workshop, held January 30 through February 2, 2001. The workshop panel included representatives from DOE, NNSA, DoD, the three NNSA laboratories, and Argonne National Laboratory. They reviewed presentations by experts in weapons design, HEDP, and ICF from the three laboratories. Topics included options for NIF deployment, other HEDP facilities that can complement NIF, and Stockpile Stewardship Program needs for HEDP, weapons experiments, and calculations for future stockpile certification.

NIF Project Status. Beginning with Key Decision Zero in January 1993, which established mission need, a series

of milestones has occurred on the NIF project that led to Critical Decision Three (March 1997), the high-level project milestone of approval to begin construction.

A major Level 2 milestone, Final NIF Supplemental Environmental Impact Statement (SEIS) Record of Decision (ROD), was approved by the Secretary of Energy on March 30, 2001. This milestone allows operation of NIF on its current site and with current environmental conditions. Another Level 2 milestone, Completion of Conventional Facilities Construction, was accomplished on schedule and on budget September 30, 2001. The DOE/NNSA-approved NIF baseline schedule calls for early light to the target chamber in June 2004 and all 192 beams to be commissioned by September 2008, which is consistent with the needs of the overall Stockpile Stewardship Program. The NIF project is proceeding as planned, and the team is working to achieve early light in FY 2003, more than a year ahead of schedule.

Program Thrusts

Progress on Construction. Overall, the NIF project is more than two-thirds complete. Major progress continues to be made at a rapid pace as the NIF team transforms itself from a "design/build" organization into an "assemble/install/commission" organization. In October 2001, the first 48 precision-cleaned and -aligned beampaths were completed in Laser Bay 2. By May 2002, NIF's beampath infrastructure (96 beams in Laser Bay 2) was completed, and the utilities required for the first laser beams were installed. In addition, the 10-meter-diameter NIF target chamber has been set and aligned in the target bay. Work has commenced in Switchyard 2 and the Target Bay to

install the diagnostic systems needed to measure the performance of the first laser beams that will be commissioned. Beam enclosures have been installed to support the transport of laser beams into the target chamber in the coming year. Additionally, the entry lobby and visitors area, including a conference room, are nearing completion. As commissioning commences for NIF's first four laser beams, construction activities will be directed to NIF's Laser Bay 1 for concurrent installation of the remaining beampath infrastructure.

We continue to make outstanding technical progress on NIF's laser and optical systems. The first 12 power-conditioning modules have been installed in one of NIF's capacitor bays and are fully energized for flashlamp firing into Laser Bay 2. The Master Oscillator Room has been activated since October 2001, operating continuously for over 6,000 hours.

The first Preamplifier Module (PAM) has been tested in the Class 100 PAM Maintenance Area (PAMMA) and installed in Laser Bay 2. Low-energy PAM operations and injection into NIF have commenced. The alignment laser system has propagated laser beams through the entire length of NIF's beampath, verifying that alignment requirements have been achieved. All of the more than 3,000 slabs of laser glass have been manufactured by two vendors. All optics—mirrors, lenses, polarizers, windows, and crystals—are in hand for NIF's first four laser beams. The Optics Assembly Building, consisting of Class 10,000 through Class 100 clean-room facilities, is operating, and all work centers required for the assembly of NIF laser components are undergoing commissioning. Over 100 of NIF's modular optical components—Line Replaceable Units—have been

installed. Recent progress has been made on the development of new ultraviolet optics polishing techniques that can allow NIF optics lifetimes greater than requirements, which will favorably impact operational costs over NIF's 30-year lifetime. We are implementing these new techniques at our vendors to provide the first ultraviolet optics for NIF's final focusing systems.

Integrated Product Teams (IPTs) have been formed to ensure that laser systems are installed to NIF's requirements and that all interface issues are coordinated during this process. An example of recent IPT activity is the activation of NIF's integrated computer control systems, including safety interlock system, alignment, shot control, and beam diagnostics systems. Management attention is focused on ensuring that safety remains the highest priority and that all aspects of Integrated Safety Management are followed. In this regard, the NIF project has made major improvements in site safety over the past year. Total recordable case rates are now regularly running at five to six times lower than national or state averages for construction projects of this type. The NIF project has logged over 2 million hours without a lost-work-time accident. NIF managers were recently awarded a "Perfect Year" Award by the National Safety Council in recognition of their first million hours without a lost-time accident.

Future Milestones. In the coming year, the NIF team's goal is to achieve early light by delivering four infrared laser beams through the entire laser chain into a diagnostics station. Soon after that, the four laser beams will be transported to the final optics assembly, where they will be converted to ultraviolet light and focused to the center of the target

chamber. This milestone, providing confidence that all NIF's systems are operating as required, will allow operational and initial experimental activities to commence. As more of NIF comes online, fundamental physics regimes for materials science, high-energy-density science, and thermonuclear ignition and burn will become accessible for study. NIF's Project Execution Plan identifies one DOE/NNSA Level 1 milestone, Beampath Infrastructure Commissioning Complete, in March 2006 and 20 DOE/NNSA Level 2 milestones between FY 2003 and FY 2008.

Associate Director for NIF Programs George Miller, in his role as NIF Director, has been tasked by NNSA to begin implementing interim governance plans for operating NIF as a national user facility. The first-draft governance plan was submitted to DOE/NNSA in April 2001, following an extended period of contribution and comment from the national security laboratories and representatives of the basic science and weapons effects communities. This plan provides for multiple levels of review and programming of NIF to ensure that the highest quality science is performed, while national security missions are met.

NIF Programs also has been requested by NNSA to provide interim management plans and draft program execution plans for the National NIF Diagnostics Program and the National NIF Cryogenic Target Systems Program. These plans were developed in collaboration with NNSA and other institutions participating in the activities. The interim management plans were approved and signed by NNSA in April 2002, satisfying a UC/NNSA performance requirement for NIF. Current experimental planning activities

for NIF are being developed through multilaboratory integrated experiment teams (IETs) that will focus on developing experimental capability on NIF beginning at the time of early light and continuing throughout the commissioning phase. Current experimental plans estimate more than 1,500 experiments will be performed before the project is completed in 2008.

2.1.6 Advanced Simulation and Computing

Advanced Simulation and Computing (ASCI, formerly known as the Accelerated Strategic Computing Initiative) is a program to dramatically advance our ability to computationally simulate the performance of an aging stockpile and the conditions affecting weapon safety. The program is designed to deliver at a steady pace significant new capabilities to support stockpile stewardship. To make the needed major advances in weapons science and weapons simulation code technology, Livermore, Los Alamos, and Sandia national laboratories are obtaining from U.S. industry dramatic increases in computer performance and information management.

Situation and Issues

ASCI White. In summer 2000, Livermore became home to the world's most powerful supercomputer at that time with the delivery from IBM of ASCI White, which is capable of over 12 trillion operations per second (12 teraops). Exceeding its contractual performance requirements, ASCI White is based on the next-generation IBM processor, node, and switch technology and constitutes another dramatic leap in performance. It consists of 512 nodes, each with 16 IBM RS/6000 processors.

ASCI White provides 8 terabytes of main memory and about 110 terabytes of global disk space.

ASCI White, received in two separate deliveries, was initially operated as two separate machines, one of which was first used as an unclassified machine. In February 2001, the two machines were merged into the classified 512-node ASCI White machine. After testing, ASCI White quickly went into production mode to support calendar year (CY) 2001 milestone runs by all three laboratories, with Los Alamos and Sandia very successfully using the machine at a distance. All three laboratories completed their CY 2001 milestones, and high usage of ASCI White continues in CY 2002. The speed, large memory, and stability of the machine are essential elements contributing to the laboratories' remarkable accomplishments using ASCI White.

Beyond ASCI White. With ASCI Purple, the next supercomputer at Livermore after ASCI White, the NNSA laboratories will have for the first time enough computing power and memory to complete high-fidelity-physics calculations of the explosion of a full weapons system with three-dimensional features. The threshold for that capability is 100 teraops, and reaching the goal quickly is vital to success in stockpile stewardship. In November 2002, DOE Secretary Spencer Abraham announced that IBM was awarded a \$290 million contract to build the 100-teraops ASCI Purple machine and a second supercomputer, a research machine called Blue Gene/L. Since the April 2002 groundbreaking, construction has progressed at Livermore's Terascale Simulation Facility, which will house the very large ASCI Purple system. ASCI Purple will be delivered to Livermore in

stages, with the first equipment arriving in 2003.

Applications Development and Validation. The unprecedented power of ASCI computers is essential to advances in simulation, but raw computer speed is not the only key to progress. The development of improved software is just as important as new hardware to increase the speed and power of simulations. The need for better algorithms is particularly great—and the challenge is particularly daunting—for software intended to run efficiently on machines using thousands of processors. In concert with the development of new algorithms and simulation software, careful attention must be given to assuring the quality of the enhanced codes. The Verification and Validation Program, which focuses on the development of improved validation tools and methods using the QMU methodology described earlier, is an important component of the overall ASCI Program.

Problem-Solving Environment. In addition to the acquisition of ASCI computers and efforts to develop, verify, and validate simulation codes, Livermore is working with Sandia and Los Alamos to improve the problem-solving environment (PSE). The success of these improvements is helping to accelerate the development and application by our weapon scientists of the new ASCI simulation codes to the problems of stockpile stewardship. Key elements of the problem-solving environment are advanced code-development tools, very large and fast data-storage facilities, high-speed communication links for both classified and unclassified data, and data visualization development.

Academic Partnerships. Academic partnerships are important to ASCI.

Livermore is working with universities through ASAP, a multiyear initiative to assist the three NNSA laboratories in meeting ASCI computational science and simulation goals. ASAP is engaging the best minds in the U.S. academic community to help accelerate the emergence of new unclassified simulation science and methodology and associated supporting technology for high-performance computer modeling and simulation.

Program Thrusts

To succeed, the ASCI Program must create leading-edge computational modeling and simulation capabilities based on advanced simulation codes and high-performance computing technologies. A new generation of weapons simulation codes is beginning to emerge, combining advanced fundamental physics models, much greater spatial resolution, and the ability to model weapons behavior in three dimensions. Taking full advantage of these codes will require computers more powerful than the best available today.

ASCI Purple and the Terascale Simulation Facility. ASCI Purple, a 100-teraops supercomputer to be sited at Livermore, will enable three-dimensional simulations with high-fidelity physics models of the performance of a full weapon system. The supercomputer will be built by IBM and powered by 12,544 microprocessors in 196 individual computers interconnected via an extremely high-bandwidth, superfast data highway. The system will also have 50 terabytes (trillion bytes) of memory, which is 400,000 times more capacity than the average desktop PC and two petabytes (quadrillion bytes) of disk storage, the content of approximately one billion books.

In addition to acquiring ASCI Purple, the Laboratory and NNSA are

working with IBM on a scalable “ultracomputer” called Blue Gene/L. IBM was awarded a contract to build the machine along with ASCI Purple. When completed, Blue Gene/L will have the peak performance of 360 teraops using 130,000 processors. It will be capable of performing an important subset of computational problems—those that can be easily divided to run on many thousands of processors. Blue Gene/L will be used by the three NNSA laboratories and the ASCI University Alliance collaborators as well as by other DOE laboratories in the future.

This expansion of Livermore’s computing power has required construction of the Terascale Simulation Facility (TSF), a \$92-million line-item project. Design of the TSF was completed in 2001, construction began in April 2002, and the first of two machine rooms is planned for completion in June 2004.

The TSF will encompass approximately 253,000 square feet, including 48,000 square feet of raised computer floor and high levels of power and cooling. An Advanced Simulation Laboratory (ASL) consisting of an assessment theater and associated offices and laboratories will allow the development of the data assessment hardware and software needed to analyze the extremely large data sets produced by ASCI scientists. TSF will also include the advanced networking infrastructure to ensure high-speed connection to other Laboratory computational resources and the backbone networks. The building will provide office and technical space for approximately 288 staff in secure and open work areas.

Advanced Simulation and Computing Campaign. As discussed in Section 2.1.3, one Stockpile Stewardship Program campaign focuses on the

development and use of 3D, high-fidelity simulation software to analyze the physics and engineering performance and safety of nuclear weapons in the stockpile. Key milestones for the campaign are aligned with the goals of other stockpile stewardship campaigns and objectives identified through the QMU methodology (see Section 2.1.2). ASCI is proving its capabilities by running “real” problems—not just benchmarks—in support of stockpile stewardship.

In 2002, the Laboratory met a major ASCI milestone with the completion of the 3D simulation of the performance of a full weapon system with 3D engineering features. It was the most complex ASCI milestone calculation to date and entailed an unprecedented level of code integration. The code performance was better than expected, and the results were in good agreement with other modern design codes run on portions of the same problem. The calculation revealed details unobtainable with previously available design codes. In another significant accomplishment in June 2001, Laboratory scientists completed a 3D simulation of the performance of a nuclear weapon secondary.

High-bandwidth connections to Los Alamos and Sandia, coupled with extensive user support services at Livermore, have allowed the machine to be used effectively by all three laboratories. Ongoing ASCI White simulations continue working to meet this year’s programmatic milestones at each laboratory.

Data Management and Visualization Capabilities. A major element of the simulation environment is very-high-performance visualization capabilities. Scientists must be able to assimilate the information from simulations

generating huge output files, possibly as large as many trillions of bytes from an overnight run. We are combining high-performance storage and networking with a visualization architecture that allows interactive exploration of huge quantities of data. Sophisticated new tools are being developed to store, manage, and rapidly move huge quantities of data and to summarize, organize, and analyze the information. Seeing and understanding the results of multi-teraops simulations is especially challenging, and the Laboratory is engaged in a variety of data-assimilation projects through ASCI's Visual Interactive Environment for Weapons Simulation (VIEWS) program. These efforts complement ASCI projects to enhance the PSE and improve Distance and Distributed Computing (DisCom).

The data management and visualization capabilities that have been developed to date at the NNSA laboratories were put to test managing the output of the 2001 ASCI milestone calculations. As an example, for Los Alamos' 3D weapon simulations that ran on ASCI White, the data were distilled on a 32-node visualization partition of the computer and sent back to Los Alamos where scientists used their capabilities to visualize the simulation results. This capability was critical for Los Alamos' effective use of the system. The data not necessary for visualization were stored in the Livermore archive. For this particular calculation, Los Alamos was able to store 12.6 terabytes (roughly equivalent to 12 million novels) in the Livermore archive in 13 hours, approximately 50 times faster than would have been possible two years earlier.

The Academic Strategic Alliances Program. Livermore is working with

universities through ASAP. University faculty, postdoctoral fellows, and students participate in research projects through a range of opportunities:

- **Strategic Alliance Centers of Excellence.** University-based centers of excellence were chosen competitively to undertake computer-based simulations of similar magnitude and multidisciplinary complexity to those required for stockpile stewardship. Each center has a five-year funding commitment and supports about 70 people. They are located at Stanford University, California Institute of Technology, University of Chicago, University of Utah, and University of Illinois. Personnel from Livermore are working with their counterparts at each center. In 2002, complementing efforts at Livermore, an ASAP researcher at the University of Chicago, for example, received a Presidential Early Career Award for Scientists and Engineers for his work.

- **Individual Task Collaborations.** These are smaller, discipline-oriented projects in computer science and computational mathematics areas identified as critical to ASCI success. Typically having short duration, these investigations are selected by an open, peer-reviewed solicitation process.

In addition, a large number of university collaborations are carried out through Livermore's Institute for Scientific Computing Research (see Section 3.4.3).

2.2 WMD Threat Reduction

Livermore applies its nuclear expertise, developed through past work in nuclear weapons development and testing and its continuing stockpile stewardship responsibilities, to the challenge of nuclear threat reduction—

nonproliferation, counterproliferation, and counterterrorism. Because the threat of proliferation is not limited to nuclear weapons, we draw on the Laboratory's broad capabilities in the biological and chemical sciences to develop the technologies, analysis, and expertise needed to deal with the proliferation of chemical and biological weapons.

These activities provide the technological base for those U.S. agencies with operational responsibility for implementing and monitoring arms control and proliferation prevention agreements, for characterizing foreign weapons programs and detecting proliferation-related activities, and for detecting and mitigating the use of WMD against the U.S. The work directly supports Goal 2 of the *NNSA Strategic Plan*:

Goal 2. Detect, prevent, and reverse the proliferation of weapons of mass destruction while promoting nuclear safety worldwide.

Strategy: Enhance the capability to detect weapons of mass destruction, including nuclear, chemical, and biological systems and terrorist threats.

Strategy: Prevent and reverse proliferation of weapons of mass destruction.

Strategy: Protect or eliminate weapons and weapons-usable nuclear material and/or infrastructure, and redirect excess foreign weapons expertise to civilian enterprises.

Strategy: Reduce the risk of accidents in nuclear fuel cycle facilities worldwide.

The primary sponsor of nonproliferation, counterproliferation, and counterterrorism programs at Livermore is NNSA's Office of Defense Nuclear Nonproliferation. Our activities are coordinated with and complement the work of other government

laboratories and agencies. Other sponsors include DoD, the U.S. intelligence community, and NNSA's Office of Defense Programs. In addition, Congress has created the Department of Homeland Security, which will manage a sizable research and development (R&D) program. Programs in NNSA, particularly those related to chemical and biological defense, have been transferred to the new department. Livermore has unique scientific, technical, and analytical capabilities that are directly applicable to homeland security, and we have established a Homeland Security Organization at the Laboratory to be responsive to the needs of the new Department.

Our ongoing counterterrorism efforts and capabilities, discussed in Section 2.2.2 Response to WMD Terrorism (as well as in Section 2.3.2 Critical Infrastructure Protection), have been called on in response to the attacks of September 11, 2001. For example:

- The Nuclear Threat Assessment Center operated seven days a week, 15 to 18 hours a day, analyzing more threats and incidents in six weeks than in the previous 12 months.
- Concrete-penetrating micropower impulse radar (MIR) assisted search and rescue operations at the World Trade Center ground zero.
- Intelligence analysts from Z Division were asked to support the Central Intelligence Agency's DDS&T's Technical Experts Cell in Washington, D.C.
- Livermore, Los Alamos, and Sandia members of the Joint Technical Operations Team (JTOT) and Radiological Assistance Program (RAP) were deployed to Washington, D.C.
- The Biological Aerosol Sentry and Information System (BASIS), developed jointly by Livermore and Los Alamos,

was deployed five months earlier than originally planned.

- The Hyperspectral Infrared Imaging Spectrometer (HIRIS) was flown over the World Trade Center rubble pile to search for and identify fugitive gas emissions.
- The Counterproliferation Analysis and Planning System (CAPS) reprioritized its work to analyze facilities and weapons programs in countries of concern.
- Development of the Detection and Tracking System (DTS) for interdicting ground-delivered nuclear or radiological devices was accelerated, and a prototype system was demonstrated.

Livermore was able to respond so immediately and broadly because we had been addressing the threat of WMD terrorism long before September 11. We partner extensively with other research institutions, universities, and industry to bring the full weight of the U.S. science and technology community to bear on the problems of homeland security and counterterrorism. We take a comprehensive, end-to-end approach and work closely with federal, state, and local response agencies to develop technologies, systems, and technical capabilities to meet real-world needs.

2.2.1 Nonproliferation and International Security

Situation and Issues

The best way to stop proliferation is at the source, through the protection and control of weapons, weapons-usable materials, and weapons-related expertise. This is particularly true for nuclear weapons because the fissile materials they require do not occur in nature and are difficult and expensive to produce. The obvious path to weapons-usable nuclear materials for proliferators or terrorists, therefore, is through illicit purchase or theft. Russia is home to vast

quantities of Soviet-legacy nuclear materials, much of which are not well secured.

Cooperative U.S.–Russian programs are securing at-risk nuclear material in Russia, disposing of excess highly enriched uranium and plutonium, and assisting in downsizing the Russian nuclear weapons complex. Despite the size and scope of this undertaking, progress is being made. For example, protection and control of hundreds of tons of weapons-usable nuclear material and hundreds of Russian Navy nuclear warheads have been upgraded. In addition, highly enriched uranium equivalent to more than 5,000 nuclear warheads has been converted to low-enrichment uranium for commercial nuclear power plant fuel. More than 40,000 former-Soviet weapons scientists have been supported in peaceful R&D projects since these programs began.

National and global security also requires technical capabilities for detecting activities indicative of WMD proliferation. Experience with Iraq demonstrates both the difficulty of detecting proliferation-related activities and the need to back up treaties with effective monitoring technology. (Iraq had signed the Nuclear Non-Proliferation Treaty and was subject to International Atomic Energy Agency inspections.) The U.S. requires capabilities for monitoring for nuclear explosion worldwide as well as technologies for remotely detecting chemical signatures and other observable events related to the development, production, and testing of WMD. Success requires long-term focus and sustained effort, as adversaries acquire more advanced technology for their WMD programs and also counter U.S. detection capabilities with increasingly sophisticated deception and denial techniques.

Program Thrusts

Securing and Disposing of Weapons-Usable Nuclear Materials. Through the Materials Protection, Control, and Accounting (MPC&A) Program, we are assisting various Russian sites to improve the protection of their fissile materials. Livermore specializes in vulnerability assessment, gamma-ray spectroscopy, access control and security system integration, and information systems. We lead the MPC&A project teams for Chelyabinsk-70 and Krasnoyarsk-45 and provide project support for seven additional site teams.

Of the various laboratories involved in MPC&A, Livermore is unique in its role with the Russian Navy. Our work at the Russian Navy facilities has been some of the most successful of the entire program. Success is attributable to the combination of a highly focused user (the Russian Navy), an excellent subcontractor and system integrator (the Kurchatov Institute), and a highly trained team of NNSA and national laboratory personnel who have built an excellent working relationship with the Russian personnel, facilitating efficient problem solving and rapid system implementation. Upgrades are under way at eight Russian Navy sites located on the Kamchatka peninsula. We also lead the effort to develop, with the Russians, the Federal Information System (FIS). This computerized nuclear materials record-keeping and database system will enable MinAtom and the Government of Russia to track nuclear material within their nuclear complex. The system has been successfully implemented with 17 Russian enterprises.

Both the U.S. and Russia have agreed to dispose of 34 metric tons of plutonium, but the path forward is complex technically, politically, and economically. Program direction for

the disposition of U.S. and Russian surplus plutonium was reviewed by the National Security Council, and as a result, the U.S. has abandoned its dual-track approach in its Plutonium Disposition Program and is focusing only on fabrication of mixed oxide (MOX) fuel to burn plutonium in nuclear reactors. Immobilization of impure plutonium in a ceramic matrix for long-term geologic disposition has been terminated; Livermore had led national activities in this area and made substantial technical progress on the approach. As a result of program redirection, Livermore has been assigned the lead for plutonium storage, packaging, and transportation activities required to prepare plutonium for disposition in Russian reactors, for storage and transportation of MOX fuel, and for treatment of wastes from the plutonium metal conversion and MOX fuel fabrication processes. Activities are in progress with the All-Russian Research and Design Institute of Production Engineering (VNIPIET, Arzamas-16) and Krasnoyarsk-26, and discussions are under way with Mayak.

Lawrence Livermore also has a role in monitoring the HEU Purchase Agreement, through which the U.S. is purchasing 500 metric tons of highly enriched uranium (HEU) from dismantled Russian nuclear warheads, which is blended down in Russia to low-enrichment uranium (LEU) suitable for commercial reactor fuel. Laboratory personnel are part of the U.S. inspection teams that travel several times a year to Russia to monitor activities at the four processing plants. We also provide training, health physics support, and logistics support for U.S. inspection and monitoring personnel. These monitoring trips, together with nondestructive assay (NDA) equipment developed by and

data analysis led by Livermore, are needed to maximize the level of confidence that the U.S. has in Russian compliance (i.e., that the LEU does indeed derive from HEU from dismantled nuclear warheads).

Downsizing the Russian Nuclear Complex. Downsizing the Russian nuclear complex is a high-priority U.S. national security goal. However, such downsizing will eliminate the jobs of thousands of Russian weapons workers. To accelerate the downsizing process, the Russian Transition Initiatives (which include the Nuclear Cities Initiative and the Initiatives for Proliferation Prevention) seek to help the affected Russian institutes create self-sustaining civilian jobs for displaced or underemployed workers.

As part of the Nuclear Cities Initiative, Livermore leads the NNSA team working with Snezhinsk and its various civilian entities to develop commercial enterprises. Since the opening of the Stella Open Computer Center (in November 2000) for commercial software development and scientific computations, several commercial enterprises have been started. The most successful so far is a partnership with LSTC, a U.S. company that sells licenses and consulting services for LSDYNA, a computer code that can calculate dynamic interactions such as car crashes.

Through the Initiatives for Proliferation Prevention (IPP), Livermore has teamed with Cyclotec Material Industries and the Biophysical Laboratory (Biofil) Ltd., a spin-off from the Russian Federal Nuclear Center Institute of Experimental Physics (VNIIEF, Arzamas-16), to develop and manufacture transcutaneous electrical nerve stimulation (TENS) devices for noninvasive treatment of traumatic

short-term pain. In response to the events of September 11 and an increase of funding available for IPP projects, we are also developing projects with several Russian biological institutes to work on, for example, categorizing strains of bacteria.

Worldwide Monitoring for Nuclear Explosions. Worldwide monitoring at the required level of sensitivity requires a detailed understanding of the propagation of signals (radionuclide, optical, electromagnetic, seismic, acoustic) that differentiate a nuclear explosion from the enormous number of background nonnuclear events (e.g., mining explosions, earthquakes, lightning strikes). Livermore is part of a four-laboratory effort to provide the U.S. government with the R&D it needs to meet its nuclear explosion monitoring goals for underwater and underground explosions. We focus on seismic R&D for the Middle East, North Africa, and Russia and on hydroacoustic monitoring of the oceans.

The development of seismic wave-propagation corrections is a central element of our efforts. We have created correction surfaces in our regions of focus, validated using ground truth from earthquake aftershock sequences, that can be used to locate seismic events from sparse regional networks to within 1,000 square kilometers. For our seismic identification effort, we have developed, in conjunction with Los Alamos, a technique for correcting amplitude variations along wave-propagation paths that dramatically improves the discrimination between earthquakes and explosions; in certain regions, we can achieve false alarm rates and missed violation rates approaching 1 percent. Our hydroacoustic work concentrates on the calibration of specific monitoring

stations and on the development of techniques for calibrating underwater sound propagation.

We are partnering with institutions around the world in applied research in seismic event location, calibration of acoustic signal propagation in the oceans, inversion of seismic data to determine the structure of the Earth, and ground truth collection in diverse parts of the world. We continue to develop and apply tools that allow us to collect ground truth information in areas where we are denied access.

Regional Security. Collaboration in science and technology can provide a mechanism for engagement in regions fraught with tension, such as the Middle East and Central Asia. Regional cooperation on relatively “safe” and mutually important transboundary topics (e.g., seismology, water resources, border security) can open channels of communication, develop indigenous capacity to improve environmental conditions and standards of living, and thereby enhance regional stability and, ideally, reduce motivations to acquire weapons of mass destruction. We are supporting several such regional confidence-building activities through cooperation and collaboration in seismology and water resources. For example, together with the U.S. Geological Survey and under the aegis of UNESCO, we are collaborating with seismological organizations from over a dozen Middle Eastern and North African countries in a seismology technical working group. We are also engaged in cooperative efforts on water management issues in the Middle East (transfer of simulation tools applicable to groundwater management) and Central Asia (workshop on radionuclide contamination of water resources).

Certification to Support the CWC.

Livermore’s Forensic Science Center is in the process of becoming the second U.S. laboratory certified by the Organization for the Prohibition of Chemical Weapons (OPCW). The OPCW is responsible for implementing the Chemical Weapons Convention (CWC), which outlaws the development, production, acquisition, stockpiling, and use of chemical weapons as well as the transfer of chemical-weapons-related technologies. The Forensic Science Center was selected for its unique capabilities in chemical analysis and forensic characterization of unknown samples. We have passed two of the three required proficiency tests (November 2001, April 2002); the next test is scheduled for October 2002. These tests involve the analysis and characterization of samples containing combinations of extremely dilute amounts of chemical warfare agents, precursor chemicals, and/or decomposition products as well as other chemicals that can complicate or confuse the analysis.

As an OPCW-accredited laboratory, Livermore will participate in testing chemical samples to determine whether the samples contain chemical weapons agents, their precursor chemicals, or their decomposition products. (Under the terms of the CWC, all chemical samples must be tested at two OPCW-designated laboratories. Congress mandates that all U.S. samples must be tested in the U.S. Currently, the nation has one designated laboratory, the Edgewood Chemical and Biological Forensic Analytical Center in Maryland.)

Technologies for Remote Monitoring.

We have developed and demonstrated the utility of a hyperspectral infrared imaging spectrometer (HIRIS) for

remote detection and identification of chemical effluents. This instrument provides simultaneous spectral, spatial, and temporal information in the long-wave infrared. HIRIS allows the identification and quantification of trace chemical species by their characteristic spectral signatures. The goal is to detect chemicals and other observables associated with the various stages of weapons of mass destruction (R&D, production, testing, storage, and use). Remote detection of these signatures would provide clues that, in conjunction with other sources of information, could be used to infer the nature of the activities that generated them.

In October 2001, we were requested to deploy HIRIS to the World Trade Center ground zero. We flew over the site and collected data on gaseous emissions from the rubble pile. These data provided valuable information to the recovery teams about potentially hazardous gases escaping from below ground.

Building on the experience gained during the development of HIRIS, we are now launching a Large-Area Search Initiative (LASI). LASI will provide a key evolutionary capability for testing sensor designs, algorithms, and operations concepts for remote hyperspectral imaging. The ultimate product will be a prototype next-generation large-area-coverage hyperspectral imaging system targeted to appropriate platforms. We are currently defining the LASI system concept, developing the system specifications, producing the initial designs, and starting fabrication and procurement activities for the first instrument.

Our technology developers work hand in hand with signatures experts, all-source intelligence analysts, and the people who develop advanced data-

exploitation techniques. This systems-level approach allows us to develop technologies that meet real-world needs, function in demanding deployment environments, and deliver information that can be readily exploited and used with confidence as the basis for nonproliferation policy and counterproliferation response. Closely tied to these technology development activities are our efforts to develop and improve the Counterproliferation Analysis and Planning System (CAPS), a tool widely used by DoD (see Section 2.3.1).

2.2.2 Homeland Security and Counterterrorism

Situation and Issues

Despite all attempts to prevent the spread of weapons of mass destruction and to reverse proliferant weapons programs, the nation must also be prepared to respond to the threatened or actual use of such a weapon against the United States. Long before September 11, Livermore was addressing the threat of WMD terrorism and the need to provide the nation with greatly improved technical capabilities for detection, response, and mitigation. We take a comprehensive approach to the problem, developing technologies and tools to counter the full range of terrorist threats (nuclear, chemical, biological, cyber, explosives). We work closely with federal, state, regional, and local response agencies to ensure that our technological solutions meet operational needs. Many of our counterterrorism technologies and technical capabilities have been deployed, both before September 11 and in its aftermath, to assist federal, state, and local governments defend against WMD terrorism.

Significant technical advances have been made and more are under way through the DOE/NNSA Chemical and Biological National Security Program (CBNP) and other activities. However, one of the greatest challenges facing the U.S. as it attempts to marshal its defenses against WMD terrorism is the need to get new technologies and systems onto the front lines of homeland security—on the borders, at seaports and airports—and into the hands of first responders—fire fighters and paramedics and the public health community. We are working closely with those who will actually use new counterterrorism technologies to ensure that they meet the needs of front-line responders and function properly in operational settings. We also make capabilities at Livermore readily accessible to all levels of response, from local fire departments to federal agencies.

We are taking advantage of the Laboratory's proximity to other national laboratories (e.g., Sandia/California, Lawrence Berkeley National Laboratory, Stanford Linear Accelerator Center), Silicon Valley, Bay Area biotechnology companies, major universities (e.g., Stanford, UC), three international airports, two international seaports, and rail and mass transit systems to develop partnerships with all major elements in the homeland security battle. We tap the expertise of Bay Area research, academic, and industry communities to augment our expertise and to ensure that the technologies thus developed can be readily transferred to the commercial and operational sector. Similarly, we reach out nationally and internationally, collaborating with experts in research institutions, universities, and industry in order to bring the full weight of science and technology to bear in the war against terrorism.

Program Thrusts

Nuclear Counterterrorism.

Livermore's Nuclear Counterterrorism Program develops improved capabilities for dealing with nuclear weapon emergencies, accidents, or terrorist incidents. We are a key participant in the national nuclear incident response groups, including the Joint Technical Operations Team (which deals with nuclear terrorism or extortion threats), the Accident Response Group (which responds in the event of an accident involving U.S. nuclear weapons), and the Radiological Assessment Program (which assists state and local agencies). Our Technical Home Team provides support for our incident response groups in the field.

We apply Laboratory capabilities in nuclear materials, nuclear weapons design, and device diagnostics to develop improved capabilities for dealing with radiological emergencies, including terrorist events. Specifically, we provide capabilities for generating accurate and detailed assessments of nuclear devices (yield-producing or radiological dispersal devices, [RDDs]), diagnosing any type of nuclear explosive, with emphasis on techniques that are rapid and nonintrusive, disabling any type of nuclear device with little or no collateral damage, planning for possible consequences, including dispersal prediction, and R&D to improve device diagnostic and disablement capabilities. Livermore maintains a deployable response capability, including the HotSpot mobile laboratory, which can be transported to any location by military aircraft to provide local radiological field support.

Nuclear Forensics. Livermore and Los Alamos play central roles in the Domestic Nuclear Event Attribution Program, sponsored by the Defense

Threat Reduction Agency (DTRA), to enhance the nation's capabilities for interpreting materials associated with a terrorist nuclear device (either yield-producing or an RDD), including post-detonation debris, to obtain clues about the origin of the device and its materials. The top-level plan for this program was finalized in June 2001, and the first program management review was held in May 2002.

We are leading the effort to develop a comprehensive debris and materials signature database and are establishing a secure communications network for operational information exchanges. We also have substantial activities in nuclear device modeling, data interpretation tools, and radiochemical readiness. In addition, we are responsible for maintaining, for DOE, a base of technical readiness in radiochemical analysis. This work builds on capabilities in nuclear chemistry and isotopic analysis developed during the years of the U.S. nuclear test program and available only at the nation's two nuclear design laboratories and actively supported at Livermore.

Radiation Detection. The radiation properties of nuclear materials, particularly highly enriched uranium, make the detection of smuggled nuclear materials an extremely difficult technical problem. Livermore's Radiation Detection Center, a center of excellence in radiation detection technologies and analysis, is coordinating the development of a number of advanced detection concepts, including a superconducting gamma-ray spectrometer and several approaches to gamma-ray imaging and neutron directional detectors.

A significant recent achievement is the Laboratory's development (in collaboration with LBNL) of the Cryo3,

a handheld electromechanically cooled germanium detector. The Cryo3 spectrometer, which does not need liquid nitrogen for operation, offers precise energy resolution and good sensitivity, plus it is lightweight and has low power requirements. Able to detect signature gamma rays from radioactive materials, the Cryo3 has clear applications for field deployment at border crossings, airports, and other locations for homeland security.

In addition to individual radiation detection technologies, we also develop integrated systems for detecting hidden nuclear materials. For example, the Detection and Tracking System (DTS) is a rapidly deployable, reconfigurable network of correlated radiation detectors and cameras that can detect and track vehicle-transported radioactive or nuclear material moving at up to freeway speeds. Upon detecting an unknown source, DTS warns security authorities, providing information about the detection, vehicle type, and location. Since September 11, DTS development has been accelerated, and a prototype system has been demonstrated in an urban environment. We are preparing for further larger-scale demonstrations of this system with added capabilities.

A significant threat to homeland security is the possibility that WMD or weapons materials could be brought into the U.S. inside maritime cargo containers. We have established the Intermodal Container Evaluation and Experimental Facility to provide unbiased testing of commercially available and prototype technologies for detecting nuclear materials inside cargo containers. Active and passive detection technologies are being tested against real nuclear materials inside real cargo containers filled with goods typical of air, sea, and truck cargo. The goal is to

define a set of affordable and reliable sensors and other components that can be retrofitted into the existing container fleet or integrated into new containers as they are manufactured for the detection and interception of contraband material. Outside agencies will be able to use this facility to make measurements using their own or national-laboratory equipment and measurement techniques. We are operating this test bed as a national service, providing a common basis for the comparison and evaluation of alternative approaches.

Biological and Chemical Agent

Detection. Livermore is a major participant in the DOE/NNSA CBNP, now within the Department of Homeland Security. We lead the CBNP R&D thrust areas in biological signatures, modeling, and prediction, and we participate in CBNP's Domestic Demonstration and Application Programs. We have made breakthrough advances in biodetection technology as well as major contributions in the decontamination and restoration arena. For this work, we leverage expertise and facilities across the Laboratory in biological and biotechnology research, chemistry and materials science, micro- and nanoengineering, and computations.

In the area of biodetection, Livermore and Los Alamos jointly developed the Biological Aerosol Sentry and Information System (BASIS) to provide biodefense for special events (e.g., 2002 Winter Olympics). BASIS was developed in close cooperation with the public health agencies (federal, state, and local) responsible for emergency response and medical operations in the event of a bioattack to ensure that it supports real-world operational needs. BASIS uses a network of distributed sampling units located in and around potential target sites. The samples are

retrieved and brought to a field laboratory where they are analyzed. The heart of the BASIS field laboratory is the Cepheid Smart Cyclor, which is based on advanced (miniaturized, real-time) polymerase chain reaction (PCR) technology developed at and licensed from Livermore. This technology is also used in the Handheld Advanced Nucleic Acid Analyzer (HANAA), which is the first truly portable, battery-powered DNA identification instrument. HANAA technology is being commercialized by Smiths Industries/ETG, with design assistance from Livermore.

Because current biodetection technology is still very labor-intensive, we are working on several next-generation concepts to provide more autonomous, rapid, and highly multiplexed detection and analysis of biological pathogens. For example, the Autonomous Pathogen Detector System (APDS) contains all the necessary elements of an end-to-end identification system and provides stand-alone, automated, continuous monitoring for biological warfare agents. We have completed construction of a second-generation prototype instrument, APDS-II, which has successfully demonstrated autonomous multiplex detection of surrogates with analysis times of approximately one minute for each measurement. We are also working on advanced concepts for autonomous and highly multiplexed detection (hundreds of simultaneous assays) of viruses, toxins, spores, and vegetative bacteria.

Biodetectors depend on unique antibodies or DNA sequences to identify and characterize biological pathogens. We are working to develop a comprehensive array of signatures and assays to support a wide range of biological detection capabilities (see Section 3.2.5).

Livermore also has extensive capabilities in chemical detection and analysis. Our Forensic Science Center has expertise and instrumentation for complete chemical and isotopic analysis of nuclear materials, inorganic materials, organic materials (e.g., chemical warfare agents, explosives, illegal drugs), and biological materials (e.g., toxins, DNA). The center develops new technologies for detecting and characterizing the source of weapons materials. It also develops microanalytical forensic techniques, new field instruments, and sample collection techniques.

This past year, we collected various program elements in chemical counterterrorism, including the Forensic Science Center and an effort in chemical signatures, into a new Chemical National Security thrust. At the same time, we restructured and expanded the Forensic Science Center so that it now comprises five technical thrusts: chemical and process modeling and information management, synthesis and materials development, analytical methods, instrumentation development and integration, and field deployment. Our goals with this restructuring are to develop a chemical national security competency that is on par with its biological counterpart and to further expand the capabilities and reach of our Forensic Science Center.

Improved Emergency Preparedness.

Through the Local Integration of the National Atmospheric Release Advisory Center with Cities (LINC), we are working with agencies in the Seattle area to evaluate the effectiveness of an approach to emergency preparedness that offers the potential for dramatically improving local response capabilities. Sponsored by DOE/NNSA's Chemical and Biological National Security Program, LINC integrates capabilities at

Livermore's National Atmospheric Release Advisory Center (NARAC, see Section 3.1.3) with local emergency management and response centers. NARAC is a national emergency response service for real-time assessments involving atmospheric releases of nuclear, chemical, biological, or natural hazardous material. NARAC can map the probable atmospheric spread of contamination in time for an emergency manager to decide whether protective actions are necessary. NARAC can also be used to evaluate specific scenarios for emergency response planning, such as optimizing the siting of bioaerosol samplers or determining evacuation routes. LINC's eventual goal is to provide a unified tool for city, county, state, and federal agencies to use in emergency planning and response.

2.2.3 Intelligence Analysis and International Assessments

Situation and Issues

One of the most critical yet difficult elements of WMD threat reduction, and particularly homeland security and counterterrorism, is gaining insight into the capabilities, intentions, and plans of persons, groups, or states hostile to the U.S. Livermore has one of the strongest capabilities in the country for analysis and research related to foreign nuclear weapons and other weapons of mass destruction, including early-stage foreign technology development and acquisition, patterns of cooperation, and foreign cyber threats. This capability is more important than ever before, as the bipolar (U.S.–Soviet) world has disintegrated into a mélange of traditional allies, regional and tribal allegiances, and transnational extremist groups.

Livermore's formal program in intelligence analysis and international assessments was established in 1965 to analyze for the U.S. intelligence community the Soviet nuclear threat and the Chinese threat shortly thereafter. Since then, our International Assessments Program (Z Division) has expanded the scope of its work to include nuclear as well as chemical and biological proliferation in small nations, rogue states, and terrorist groups.

Program Thrusts

All-Source Analysis. We conduct all-source analysis and research related to foreign development and deployment of nuclear weapons and other weapons of mass destruction. Our assessments provide important input to policy makers and diplomats as they develop strategies for U.S. responses to events affecting national security.

We evaluate nuclear proliferation risks in world “hot spots,” focusing on threshold states with difficult or hostile relations with the U.S. and those located in politically unstable regions. Nuclear programs in Iran, Iraq, North Korea, India, and Pakistan are of major concern. Early-stage foreign technology development and acquisition programs are of particular interest as cooperation among proliferant countries has grown to include a full spectrum of weapons technologies.

We also analyze the status of nuclear weapons and weapon materials in Russia and China. Both countries pose concerns related to nuclear proliferation; each may be the source of nuclear materials or technology whose transfer could accelerate indigenous WMD programs. Russia's economic and political instabilities put severe stress on existing and future controls for safeguarding nuclear material and weapons

inventories. China is of concern because of its uneven history related to arms control and nonproliferation and its often-strained relations with the U.S.

The Laboratory's experience and capabilities in nuclear weapons development, testing, and stewardship as well as in biological and chemical science provide the critical foundation for our integrated assessments of WMD proliferation and WMD terrorism. The ability to do integrated assessments is essential, because nuclear, chemical, and biological weapons programs are interrelated in some countries of concern, while others are pursuing chemical and/or biological weapons in lieu of more costly and complex nuclear weapons. In addition, chemical and biological weapons are more likely choices than nuclear weapons for terrorist groups attempting to make their own devices. We are aggressively expanding our capabilities in biological weapons (BW) assessments. Our goal is to develop a BW assessment capability on par with our expertise in nuclear assessments.

Nuclear Threat Assessment. The DOE/NNSA's Nuclear Assessment Program was established in 1977 to provide a national capability for correctly and expeditiously assessing the credibility of communicated nuclear threats. This operational capability consists of a small group of professionals who are collectively knowledgeable in nuclear explosives design and fabrication, nuclear reactor operations and safeguards, radioactive materials and hazards, linguistics analysis, behavioral analysis and profiling, as well as terrorist tactics and operations. The assessor teams are organized into specialty teams, operating in secure facilities at the three participating DOE/NNSA contractor sites. An Assessment Coordinating

Center at Livermore directs credibility assessment operations for DOE/NNSA and provides a single point of contact for federal crisis managers during emergency operations.

Shortly after its inception, the Nuclear Assessment Program became the central point of contact and action office within the DOE/NNSA for assessing and monitoring illicit nuclear material trafficking incidents worldwide. Selected elements of the program are routinely used to provide technical support to the law enforcement, diplomatic, and intelligence communities. Such support activities include real-time assessments of nuclear threats and black market transactions, participation in FBI-designated special events, and instruction for DOE/NNSA courses on nuclear crime at various national and international training venues. Since the terrorist attacks on September 11, there has been a dramatic increase in requests for these services.

Information Operations. We provide technology and expertise to enable the U.S. to exploit information technology as a defensive strategy and to defend critical infrastructures against nation-state, terrorist-group, and hacker attacks. Our Information Operations and Assurance Center (IOAC) works directly with the U.S. intelligence community to address its need to gather, sort, mine, and interrelate the vast quantities of collected intelligence information. We apply Livermore capabilities in computing science and information technology to the problem of information overload and the need to find and relate the kernels of critical information amidst the enormous volumes of data collected by the intelligence community.

Specifically, IOAC develops tools for modeling large information networks, graphically visualizing them, and

analyzing them for attributes and patterns of interest. We then use these tools to determine the vulnerabilities of specific information systems to attack, the consequences of an attack, and the actions that can be taken to protect those systems. A major thrust is the development of a knowledge representation that can describe the interrelationships among objects in various data and information repositories. Methodologies for analyzing and visualizing data relationships and for executing queries that span multiple information repositories are also being developed to enable users to understand those relationships and identify previously unknown linkages and associations.

Export Control. We provide technical knowledge and intelligence information needed to help control U.S. exports that could support WMD proliferation. Accurate determination of the end uses and endusers for exports facilitates legitimate commerce while meeting U.S. multilateral obligations to limit the spread of WMD programs. We work with DOE Headquarters and six other national laboratories to integrate technical expertise with available intelligence community resources and provide all-source multidisciplinary evaluations of the impact of technology, materials, and expertise when transferred to countries of concern. We also review proposals for the Russian Transition Initiatives, International Science and Technology Center (ISTC), Science and Technology Center of Ukraine (STCU), and, since 2000, contracts referred to the U.S. government for Iraqi purchases under the United Nations' Oil for Food Program.

International Security Research Facility. Ground was broken in April 2002 for the \$24.6-million International

Security Research Facility, which should be completed in 2004. The facility will be a two-story building with gross floor area of 64,000 square feet housing some 180 people. It will provide space for electronic archiving, a flexible secure conference center, an information-processing hub, an imagery exploitation laboratory, a communications vault, and an emergency operations center. This new facility is needed to enable the Laboratory to take advantage of the digital revolution in the intelligence business and to accommodate expanding programmatic needs for space in a secure compartmented information facility (SCIF).

2.2.4 Integrating Policy and Technology

Situation and Issues

The Center for Global Security Research (CGSR) brings together diverse expert communities to learn how science and technology can enhance national and international security. The center also supports CGSR fellows who study complex issues at the nexus of technology and policy. CGSR taps the national security expertise resident at Lawrence Livermore, including its broad and deep base of science and engineering and its world-class capabilities in analysis, modeling, and simulation. The center sponsors workshops in which Laboratory scientists, policy makers, academics, and other national security experts interact, giving all involved a better understanding of what national security policy needs from technology and what technology can and cannot do for policy.

Program Thrusts

CGSR focuses on four areas related to the intersection of technology and

policy: the reduction of threats associated with WMD, the security implications of emerging technologies, the anticipation of threats to national and international security, and the future role of military forces. The center partners with national and international security organizations, including Stanford University's Center for Strategic and International Studies, UC San Diego's Institute for Global Conflict and Cooperation, the Monterey Institute of International Studies, the National Defense University, and the International Institute for Strategic Studies in London. Participants in our studies and workshops are drawn from throughout the U.S. government—including the Departments of Commerce, Defense, Energy, Justice, and State; the Federal Bureau of Investigation; the White House Office of Science and Technology Policy; members of Congress; the national laboratories; and U.S. and foreign universities and industry.

CGSR sponsors major annual "futures" projects that include a series of workshops culminating in a conference and published proceedings. "Whither Deterrence? Strategies for the Future and Implications for Nuclear Weapons" was the topic for 2001, and "Science and Technology for National Security: The Next 50 Years: Pioneering the Endless Frontier" is the subject for 2002.

2.3 Meeting Other National Security Needs

Livermore works with the Department of Defense and other government agencies to leverage Laboratory capabilities. The goals are to provide research and development support beyond the capabilities of the

agencies' in-house resources and to meet future national security needs.

2.3.1 Department of Defense

Situation and Issues

DoD is engaged in an effort to transform U.S. defense strategy and force structure to reflect post–Cold War threats to national security. The overriding strategy is to maximize the effectiveness of U.S. armed forces by exploiting superior technology.

Livermore has experience and expertise in many areas of science and technology directly relevant to future defense needs, including missile defense, solid-state lasers, armor/anti-armor materials and munitions, micro- and nanofabrication, remote sensing, and sensors and sensor networks. Livermore also has a long history of collaboration with DoD. For example, for more than a decade, we have been engaged in a DOE–DoD advanced conventional munitions technologies program for which we have developed new energetic materials and computer tools for the design and analysis of munitions. As a result of this partnership, the Livermore-developed high explosive, LX-14, is now used in the TOW and Hellfire missiles, and our CHEETAH code is widely used by DoD to predict the performance of propellants and explosives and evaluate formulations of new energetic materials.

Program Thrusts

Counterproliferation. CAPS is widely used by U.S. military planners to analyze the WMD production capabilities of countries of concern and assess interdiction options. CAPS combines commercial and specially designed software so that the scientific heart of the product is essentially

invisible to the user. Software in CAPS provides users with ready access to sophisticated applications codes. For example, CAPS can couple to NARAC (see Section 3.1.3) to obtain 72-hour forecast winds as input to assessments of the consequences (e.g., toxic releases) of interdiction options.

CAPS is regularly and widely used. Its Websites on three separate classified networks are routinely visited by more than 1,000 military planners each month. Analytic requirements for CAPS are provided from all U.S. combatant commands through the U.S. Strategic Command. This past year, CAPS completed a series of extremely high-resolution analyses of sites in countries selected by DoD, and the program is maintaining a regular production schedule in support of counterproliferation analysts from all the combatant commands. We also responded to requests for analyses following the events of September 11.

Extreme Communications. Livermore researchers are teaming with academia and industry to develop powerful new capabilities for secure, high-capacity communications links suitable for transporting data and images over long ranges (tens to hundreds of kilometers). These projects, funded by Laboratory Directed Research and Development (LDRD) and the Defense Advanced Research Projects Agency (DARPA), are developing technologies and concepts at the system, subsystem, and component level.

The Coherent Communications, Imaging, and Targeting (CCIT) project, sponsored by DARPA, aims to develop advanced micro-electro-mechanical systems (MEMS) mirror and wavefront sensor technologies with potential applications in multigigabit-per-second, secure, free-space communication links,

aberration-free three-dimensional imaging, and targeting at ranges of 1,000 kilometers or more.

The Secure Air–Optic Transport and Routing Network (SATRN) initiative, funded by LDRD, is developing and demonstrating key enabling technologies for long-range, secure, high-capacity, air–optic laser communications links suitable for transporting MASINT and SIGINT data. SATRN has successfully demonstrated the system concept in open-air tests between the Livermore site and the top of Mount Diablo (29 kilometers apart).

Technologies and capabilities developed under the SATRN effort are being leveraged in the DARPA/ATO Terahertz Optical Reachback (THOR) laser communications program, for which LLNL is developing novel passive terminal technologies. Livermore researchers are also teaming with ITT Industries, winner of the THOR network architecture award.

Advanced Conventional Munitions. Livermore contributes its expertise in energetic materials, advanced conventional munitions, laser and electro-optics systems, conflict simulation, and consequence analyses to the development of precision weapons systems that will allow the U.S. military to destroy adversary targets while minimizing collateral casualties.

One area of special interest is the development of improved capabilities to defeat hardened and deeply buried targets. In one project, we are working with DoD to improve the capability of low-velocity cruise missiles to penetrate hard targets. Laboratory researchers have tested a prototype of a new multicharge precursor warhead, consisting of a cluster of small charges with a single large charge in the back. It is designed to efficiently create a large hole in a

hardened target for the cruise missile to penetrate virtually unimpeded.

Missile Defense. Several major projects at the Laboratory are supporting active defense efforts in DoD. For the Ballistic Missile Defense Organization, we are exploring the use of remote sensing instruments and spectroscopic analysis for ballistic missile defense applications. Our goal is to develop technology for real-time characterization of impact and debris to provide battlefield commanders with a rapid identification of enemy warheads with chemical and biological agents. We are looking at the optical signatures that might be accessible to remote sensing instruments following the intercept of a hostile missile. The Livermore-developed echelle grating spectrometer (EGS) is the principal sensor component of the Remote Optical Characterization Sensor Suite (ROCSS). ROCSS has been integrated into a Gulfstream II aircraft and was successfully demonstrated in the May 2002 full-scale Integrated Flight Test (IFT-8) conducted at the Ronald Reagan Ballistic Missile Test Site at Kwajalein Atoll, Republic of the Marshall Islands. There, it collected spectra on the interceptor rocket plume during ascent and imagery of the intercept itself. ROCSS is slated to support several flight tests per year through 2007.

In support of the Army's Space and Missile Defense Command, the Laboratory is also working with industrial partners to develop a 100-kilowatt average-power, solid-state laser to be deployed on a mobile battlefield platform. High-power laser systems are leading candidates for an enhanced air-defense capability. In 2000, we brought into operation a 10-kilowatt prototype laser and tested its ability to damage selected materials. The laser was

delivered to the High-Energy Laser Systems Test Facility (HELSTF) at White Sands Missile Range in 2001. The laser and an associated technology each earned R&D 100 Awards in 2002.

In another project, we demonstrated critical capabilities that future microsatellites will need to perform complex autonomous operations in the proximity of other space objects using an engineering test vehicle (ETV). With its novel object-tracking system and miniaturized propellant system, the ETV has repeatedly succeeded in docking with another object in dynamic experiments on an air table that simulates zero-gravity conditions.

Conflict Simulation and Situational Awareness. The Joint Conflict and Tactical Simulation (JCATS) represents the culmination of more than 20 years of work at Livermore in developing interactive conflict simulation models for DoD. JCATS allows training, planning, and analysis from the global scale to individuals fighting inside a multistory building. It can model all types of terrain (land, marine, air, urban), different types of military assets and weapons, and even the level of fatigue of individual soldiers. JCATS is used by more than 70 organizations, including the U.S. military commands and services, intelligence agencies, State Department, Secret Service, and DOE site security, for training, planning, and analysis of a wide spectrum of military and security operations. JCATS has also been used to evaluate alternative means of providing the battlefield capabilities that antipersonnel landmines afford the warfighter. Post–September 11, we provided a specially modified version of JCATS to the U.S. Secret Service.

We are now focusing our conflict simulation effort to support the concept

of a Joint Total Operational Planning System (JTOPS). Our objective is to provide DoD and other users with extraordinary comprehension of their operational world so that they can plan, train, execute, and monitor their missions. Our vision is to create an “environment” in which the situation of a single individual or event can be seen, felt, and understood not only in situ but also by a remotely based support team. Many technical components comprise JTOPS—conflict simulation, network architectures, communications, sensors, etc.—all linked and integrated through the JCATS architecture.

2.3.2 Critical Infrastructure Protection: Situation and Issues

Since September 11, the Laboratory has been focusing even greater attention on understanding the threats to and vulnerabilities of the U.S. civilian population and infrastructure. We are considering a range of possible threats, emphasizing WMD and the disruption of information systems. We are concentrating on identifying and understanding gaps in preparedness and response capabilities and the associated opportunities for technology.

Program Thrusts

Computer Security. We assist any DOE facility that experiences a computer security incident with analysis, response, and restoration of operations. The Computer Incident Analysis Center (CIAC), located at the Laboratory,

serves as DOE’s watch and warning center, notifying the complex of vulnerabilities that are being exploited, specifying countermeasures to apply, and providing a picture of the attack profile. CIAC also develops science and technology solutions in support of computer network defense. In FY 2001, the CIAC incident response team issued 144 bulletins and 4 alerts logged from 47,813 detected incidents at 47 DOE sites. Although these figures represent an increase of more than a factor of six in the number of incidents detected and reported, the number of successful compromises decreased.

CIAC also develops and implements a variety of computer security tools. These include the Network Intrusion Detector (NID) to detect intrusions based on network monitoring packet analysis, the Alarms System for intrusion detection on Unix systems, and SafePatch, which determines the version of system software running on the host platform and downloads the correct software patches to update that system. These systems are widely used through government. For example, NID is a standard tool for DOE and DoD computer systems, and SafePatch is a key element of the Air Force’s cyber-defense program.

Security Technology Development. With support from DOE’s Security Technology Development Program, Livermore develops a variety of advanced technologies to deal with threats to security that continue to grow more sophisticated. Principal efforts are in:

- Computer security technology for intrusion detection, vulnerability

assessment, and system patching. Some of Livermore’s tools are mentioned above.

- Physical security systems mainly associated with sensor and security automation technology and improvements to the Argus system. Argus is the security alarm system and access control system used at Livermore and a variety of other DOE and DoD sites. With continual support for technology development, Argus has been constantly upgraded over the past decade, keeping the system state-of-the-art compared to other operational security systems (see Section 3.1.1).
- Materials control and accountability technology for improved methods to characterize and measure nuclear materials and their isotopes. Projects include the continuing improvement of nondestructive-assay (NDA) techniques originally developed at Livermore and now used throughout DOE and by the International Atomic Energy Agency (IAEA), Euratom, MinAtom, and other organizations devoted to tracking nuclear materials.

Risk and Vulnerability Assessment.

The Laboratory is a major scientific contributor to the discipline of risk assessment and risk management and has applied risk and decision theory methodologies to a wide range of hazardous endeavors, both internal to the Laboratory and for the public sector. Through our participation in DOE’s Vulnerability and Risk Assessment Program, we have systematically evaluated vulnerabilities, interdependencies, and computer and

physical security at critical facilities around the country.

We have made systematic assessments of the threat environment, computer architecture, physical and operational security, policies and procedures, impact analysis, interdependencies, risk characterization, and possible mitigation measures for the 2002 Winter Olympics, eleven electric and gas infrastructures (most of which are multi-state), and several independent service operators (ISOs), including the California ISO during the electrical energy crisis of summer 2001.

We have also analyzed the vulnerability of buildings, dams, and other structures to catastrophic damage from earthquakes and explosive events, including the effects of earthquakes on major bridge structures (including the Golden Gate and San Francisco–Oakland Bay bridges), the structural integrity of nuclear material shipping containers for various impact scenarios, and the likely damage resulting from the explosion of natural gas storage tanks in a suburban environment.

These efforts are being integrated in a new program in homeland security analysis to identify and understand gaps in preparedness and response capabilities and the associated opportunities for technology. We are conducting systems studies to gain insight into the effectiveness of alternative approaches to mitigating damage, including the efforts mentioned above. In parallel, we are interacting with representative state and local entities with front-line responsibilities for homeland security so we can gain an operational understanding

of relevant city or regional systems, including law enforcement, public health, emergency response, and environmental protection. We are also working with local agencies to define technology demonstration programs that will serve as field tests to facilitate rapid deployment of technologies.

Support to Law Enforcement. Over the years, Livermore's Forensic Science Center (FSC) has responded to many requests from law enforcement for assistance in forensic analysis of unique samples. The center has been brought in to analyze counterfeit bills, biotoxins, methamphetamine samples, suspect chemical-warfare specimens, and nuclear contraband. It has characterized explosive traces from the Unabomber case and the Fremont serial bomber; performed forensic sleuthing related to the Riverside "mystery fumes" case; and provided key sample analyses for the Glendale "Angel of Death" case. Recently, the FSC assisted Livermore police by rapidly identifying a vapor at the scene of a suicide, enabling law enforcement personnel to take appropriate protective measures and complete their investigation. At the height of the anthrax incidents, the center was called on to analyze a suspect powder found at a local business. Livermore scientists worked through the night to complete the analysis, confirming that the powder was harmless. The FSC also analyzed Capitol Hill offices as requested following anthrax decontamination.

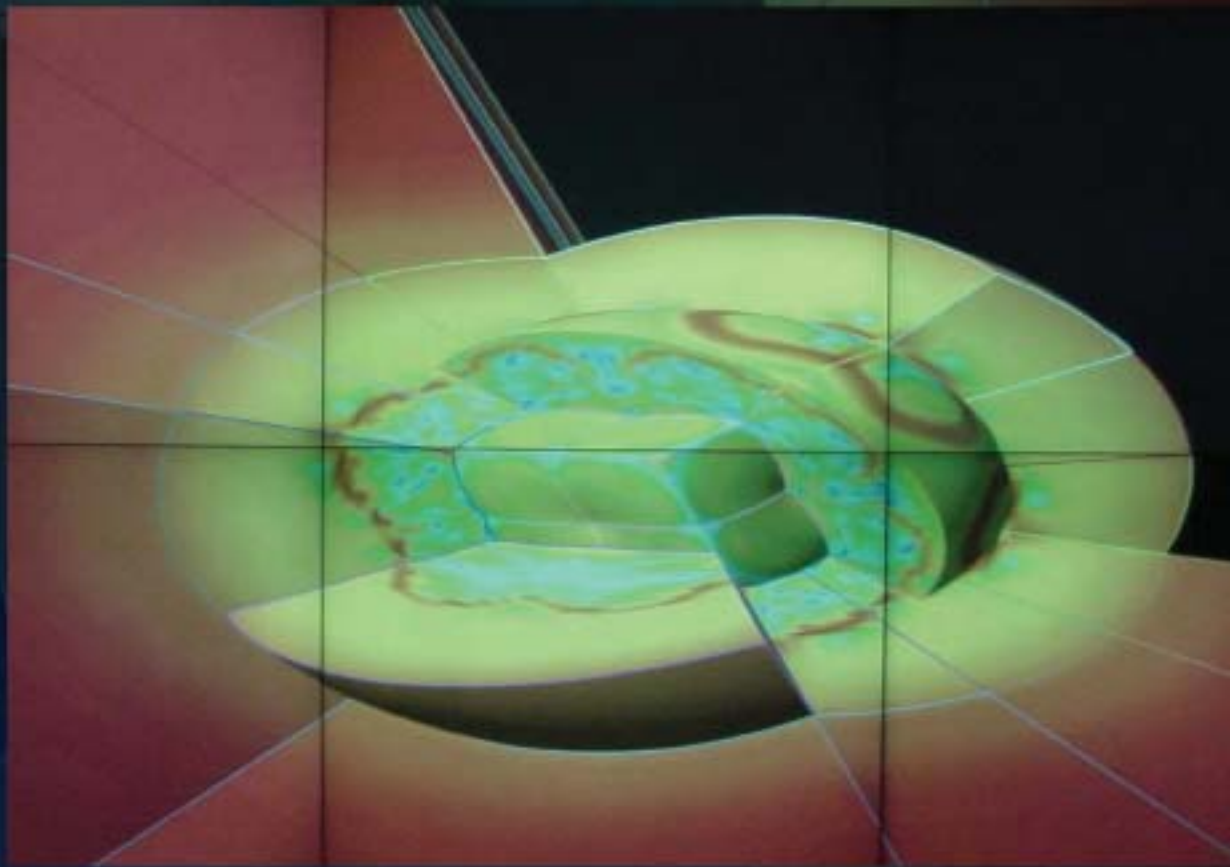
Law enforcement can also benefit from the center's technologies developed

initially for onsite inspection of arms control treaties, detection of WMD proliferation activities, and response to WMD incidents. An example is our 54-pound, portable gas chromatograph/mass spectrometer (GC/MS), a system for quickly analyzing samples at the scene of a crime or accident. Other technologies with potential application to law enforcement include thin-layer chromatography (TLC) and solid-phase microextraction (SPME). Our portable TLC system, which can simultaneously analyze 100 samples for high explosives and other chemicals, can also be used to collect minute samples indicative of the presence of illegal drugs or other chemicals of interest to law enforcement agencies. SPME samples can be secured, preserving chain of custody, for later analysis or inserted directly into the portable GC/MS for immediate analysis.

SECTION 3

Institutional Plan FY 2003–2008

Laboratory Science and Technology— Enduring National Needs



The three-dimensional Djehuty code simulates the evolution and structure of stars. Djehuty is helping scientists to understand high-temperature physics and perform accurate numerical simulations of complex physical reactions. Understanding thermonuclear fusion, the prime stellar energy mechanism, is an important part of the Laboratory's national security mission.

THE Department of Energy has enduring missions that are vital to the national interest. In addition to providing for national security, the Department pursues other priorities that include enhancing the nation's energy security, developing and making available clean energy technologies, cleaning up former nuclear weapons sites, developing effective and timely approaches for nuclear-waste disposal, and applying DOE's research capabilities to advance fundamental scientific knowledge and contribute to U.S. technological innovation.

Major Research Areas

Lawrence Livermore supports these DOE mission priorities with major research activities in selected areas. We pursue projects in which we can make unique and valuable contributions. These activities build on and reinforce the Laboratory's key strengths. The nation benefits from the application of our special skills to a wide range of national problems and from the cross-fertilization of ideas. In turn, program diversity keeps the Laboratory vital and helps to sustain the multidisciplinary base needed for national security work. Livermore has programs and plans in three major research areas.

Energy and Environmental Programs.

Long-term research is needed to help provide the nation abundant, reliable energy together with a clean environment. The importance of these efforts has been reemphasized by recent events and trends—state and regional energy crises, international developments following the September 11 terrorist attacks, growing gas and oil imports, and increasing concerns about the Earth's environmental legacy. Livermore's energy and environmental programs contribute to providing the scientific and technological

basis for secure, sustainable, and clean energy resources for the U.S. and to reducing risks to the environment. Our efforts address the interconnecting areas of energy, environment, and national security. They focus on critical thrust areas in which the Laboratory can make a difference: nuclear systems and materials management; global energy, carbon, and climate issues; and environmental risk reduction.

Work in these areas draws on and helps to strengthen the special capabilities that the Laboratory needs for its national security mission. The projects benefit from Livermore's multidisciplinary approach to problem solving as well as very advanced computers and simulation capabilities. We have an ability to achieve a comprehensive understanding of issues through end-to-end analysis, and we have a research approach that includes basic science, computational modeling, laboratory and field experiments, and prototype development.

Bioscience and Biotechnology.

Bioscience research at the Laboratory enhances the nation's health and security through technological innovation. We leverage our physical science and engineering capabilities and focus on molecular biology, genetics, computational biology, biotechnology, and health-care research. Our basic and applied research efforts are directed at meeting vital national needs—understanding causes and mechanisms of ill health, developing biodefense capabilities for homeland security, improving disease prevention, and lowering health-care costs. The cross-fertilization of ideas that occurs at a broad-based national laboratory is important to these programs, as is the availability of the latest technologies in physical sciences and engineering.

Fundamental Science and Applied

Technology. We also pursue initiatives that bolster Livermore's research strengths, further develop the science and technology areas needed for the Laboratory's national security mission, and contribute to solving important national problems. Many of these activities are funded by DOE's Office of Science or are supported by Laboratory Directed Research and Development (LDRD) to extend Livermore's capabilities in support of current and new mission requirements.

For example, in FY 2002, the Office of Science directed over \$50 million to the Laboratory to help satisfy current and future DOE missions. Program areas that benefit from this funding include fusion energy, biology and environmental research, high-energy physics, nuclear physics, nuclear safety and security, basic energy sciences, novel materials, and advanced computations. Specifically funded projects that feature extensive outside collaborations include the Next Linear Collider, the Relativistic Heavy Ion Collider at the Brookhaven National Laboratory, and the Linac Coherent Light Source at Stanford as well as the Joint Genome Institute.

Alignment with DOE's Strategic Direction

Livermore's strengths are well matched to DOE's needs (and selected special needs of other customers), particularly in areas with high payoffs that entail significant scientific and technical risk. In addition to our national security efforts, we contribute to DOE's strategic goals in:

Energy Resources. Promote the development and deployment of energy systems and practices that will provide current and future generations with

energy that is clean, efficient, reasonably priced, and reliable.

Environmental Quality. Aggressively clean up the environmental legacy of nuclear weapons and civilian nuclear research and development programs at the Department's remaining sites, safely manage nuclear materials and spent nuclear fuel, and permanently dispose of the nation's radioactive wastes.

Science. Advance the basic research and instruments of science that are the foundations for DOE's applied missions, a base for U.S. technology innovation, and a source of remarkable insights into our physical and biological world and the nature of matter and energy.

Partnerships and Collaborations

Much of our work to meet enduring national needs is executed in partnership with industry, academic institutions, and other laboratories. Partnering activities span a wide range—from very large-scale strategic alliances to individual technology licenses, academic research, educational outreach, and support for the small business community. Often partnerships and collaborations are the most cost-effective way for us to accomplish programmatic goals. In addition, Livermore has a responsibility to move appropriate technologies developed in the course of our mission work into the marketplace, where the advances can have the maximum positive impact on the U.S. economy or other important national priorities.

3.1 Energy and Environmental Programs

The future security of the U.S. and the world depends on increased access to clean energy and on the preservation of a healthy environment. Dependable, affordable, and environmentally sound

energy for the future requires a comprehensive long-term strategy that entails the development and use of leading-edge technologies. Many important advances are needed that will require effective partnerships between private industry and government.

Livermore's role is to apply its core capabilities to enduring national needs that require innovative science and technology. Livermore is a leading science and technology laboratory in energy and environment. As a resource to government, in partnership with industry and universities, we develop new energy and environmental capabilities for the nation. Our expertise and accomplishments in these areas enhance the Laboratory's primary mission in national security in two ways:

- By focusing our energy and environmental programs in research areas that have important national security aspects, such as nuclear materials management. These activities are natural extensions of—and are often tightly connected with—our national security mission.
- By extending the scale, technical reach, demonstration orientation, and expertise that support Livermore's national security mission. The programs benefit from the Laboratory's widely demonstrated ability to combine laboratory experiments and terascale computing to make dramatic advances in scientific understanding and technology demonstration. These activities add to the intellectual vitality of the Laboratory and help support the technology base needed to provide for national security. For example, expertise in geophysics and atmospheric science are needed to monitor nuclear test activities worldwide and to model atmospheric releases of hazardous substances.

The principal goals of our energy and environmental programs are to provide the scientific and technological basis for secure, sustainable, and clean energy resources for the U.S. and to reduce environmental risks to U.S. interests. Reaching these goals will require significant technological advances as well as broad cooperation among institutions. Our efforts focus on three critical areas in which the Laboratory can make a significant, positive difference.

Nuclear Systems and Materials

Management. With the need for additional sources of clean energy, there is a resurgence of interest in nuclear power as a contributor to the nation's energy supply. The National Energy Policy recommends that "the President support the expansion of nuclear energy in the United States as a major component of our national energy policy." The report further recommends that the U.S. "should re-examine its policies to allow for research, development and deployment of fuel conditioning methods . . . and enhance proliferation resistance." Even in the absence of an expansion of nuclear energy, DOE will be responsible for a vast array of nuclear materials for generations to come. Nuclear materials management is a fundamental, compelling, and enduring mission of the Department.

The Laboratory's diverse technical capabilities are being applied to address national and international technical issues associated with the safe and secure use of nuclear systems and materials. We are helping DOE to address some of the most significant scientific challenges in the Yucca Mountain Program to develop a repository for high-level radioactive waste. In addition, Livermore's Fission

Energy and Systems Safety Program is engaged in a variety of projects managing nuclear materials, providing nuclear safety assessments, developing security system technologies, and investigating advanced approaches to closing the nuclear fuel cycle.

Energy, Carbon, and Climate. The Earth's resources are finite, and expanding economies around the world are putting stress on traditional sources of energy and natural systems. Current technologies are not adequate to meet growing demands, and human activities (such as reliance on burning fossil fuels to meet energy needs) continue to increase the atmospheric concentration of CO₂ and other greenhouse gases. Significant, large-scale innovations are needed to provide clean, accessible, non-resource-depleting energy production.

The Laboratory is engaged in both basic and applied research efforts to better understand the links between energy use (and other human activities) and climate change. In addition, in areas where the Laboratory has special expertise, we will selectively pursue research and development of advanced energy technologies focused on end-use efficiency, the use of lower-carbon fuels, and CO₂ sequestration. Livermore also focuses on important aspects of carbon management and contributes to scientific and technical assessments of carbon-management strategies. We will also develop a better understanding of the environmental consequences of energy generation and use, which will drive technology selection and implementation.

Environmental Risk Reduction. DOE's environmental responsibility, dealing with the legacy of Cold War nuclear weapons production, is a major task. At Livermore, we are developing a better understanding of the underlying science related to the fate, transport, and effect

of radionuclides in the environment. In addition, we are developing technologies to characterize and remediate contaminated groundwater faster and more cost efficiently than previously possible. Opportunities exist to accelerate cleanup at DOE contractor sites and to apply the technologies more broadly.

The Laboratory also has extremely sensitive techniques for determining the mutagenic and carcinogenic potency of chemical pollutants. We will develop new technologies that reduce the time and cost to achieve specific risk reductions, and we will advance the scientific basis for risk assessment and regulatory reform. Livermore is capable of providing assessment and effective response capabilities needed to deal with a wide range of natural and man-made risks and disasters that pose threats to the environment and international security.

3.1.1 Nuclear Systems and Materials Management

Situation and Issues

Nuclear Materials—A Long-Term Issue. DOE will be responsible, both internationally and domestically, for nuclear materials for generations to come. Proper management of nuclear materials is an important strategic objective of DOE that is tied to the Department's missions in national security, energy resources, and environmental quality. National security concerns give rise to the need to develop proliferation-resistant nuclear energy technologies for international use as well as technologies to better manage and control nuclear materials. Current environmental and safety issues—waste cleanup, interim storage, and long-term repositories—dominate domestic

concerns. There is also a resurgence of interest in exploring next-generation nuclear technologies to provide energy security and better manage the nuclear fuel cycle.

Livermore's Capabilities and Contributions. Livermore is outstanding among U.S. national laboratories in both the scope and focus of nuclear activities. In addition to weapons research and development, we work on aspects of nuclear systems and materials associated with civilian use in projects that address the full range of the nuclear fuel cycle. Our activities span national security aspects (materials disposition, waste management, and proliferation-resistant technologies) and energy and environmental concerns (technologies for storage, improved safety and security, transportation, repositories, and cleanup). This experience base gives Livermore the expertise and ability to provide key elements to assist in the development and pursuit of a comprehensive national approach to management of nuclear systems and materials.

Program Thrusts

Yucca Mountain Program. On February 15, 2002, the President endorsed DOE's recommendation to store high-level nuclear waste in an underground repository at Yucca Mountain, Nevada, and Congress subsequently provided its support for DOE's decision. DOE wants to move ahead on the first steps toward license application. For the Yucca Mountain Program, we have played a major role in the design of the storage canister and engineered barrier. We also are pioneering the approach of using waste-generated heat to keep the storage environment dry and leading in the development and evaluation of waste

package materials and designs. Livermore staff members led the preparation of three of the nine process model reports—waste package, engineered barrier system, and near-field environment—that provided the basis for the Secretary's site recommendation to the President. We are now working to support major project milestones toward license application, and in these efforts we have placed significant emphasis on achieving high quality assurance.

Livermore's focus is on developing a system of engineered barriers surrounded by natural barriers to contain the radioactive waste. Because there is no long-term performance history about how modern materials, placed in a geologic site and subjected to initially high temperatures and radiation, will behave over long time periods, much of our development work is based on accelerated aging tests of materials and systems and on predictive models. We are conducting materials performance tests to confirm that the waste packages will maintain their integrity for thousands of years. This information is centrally important to decisions about licensing the site and how it is to be operated.

The Laboratory has been testing the materials for making waste packages and researching the site's geology to accurately predict the effect on nearby geology of the buried wastes. In addition, using Livermore's supercomputers and new codes to simulate the geologic evolution of the repository, we are conducting pioneering analyses of how heat affects the mountain. The simulations are being used to predict the temperature evolution surrounding the buried waste and the possible means by which water will enter the repository tunnels over geologic time periods.

The reactive transport modeling capabilities that Livermore is developing are a recognized resource for other DOE environmental restoration plans and projects—at Hanford and at Idaho.

Nuclear Safety. Livermore's Fission Energy and Systems Safety Program works with the Nuclear Regulatory Commission (NRC) to develop software and computer-system design guidance that it uses to evaluate the design of safety-critical systems for U.S. plant retrofits. Overseas, where new nuclear power plants are being built, regulators and designers are using this state-of-the-art guidance to help ensure plant safety. We also evaluate commercial software for use in critical safety systems.

In addition, Laboratory experts, using sophisticated risk assessment models, work with DOE and NRC to analyze the transportation of spent nuclear fuel. In the past year, Laboratory experts participated in the review of 10 shipping package applications and discovered three flaws in new package designs. These packages were redesigned to eliminate the flaws before manufacture, saving the nation tens of millions of dollars. We also review safety analysis reports for packaging with regard to federal regulations and develop evaluation criteria for NRC and DOE.

We have started three projects related to computational materials science for advanced reactors. This capability grew out of the Laboratory's work in the Stockpile Stewardship Program. The projects, based on first-principles physics, are developing computational materials science models to understand irradiation damage in various nuclear materials. Projects address the engineering properties and phenomena of swelling, embrittlement, and stress corrosion cracking.

Nuclear Security and the Argus Security System. As part of its nonproliferation mission, Livermore contributes to DOE's Material Protection, Control, and Accounting (MPC&A) Program to improve the security of weapons-usable nuclear materials in the former Soviet Union (see Section 2.2.1). For example, we participate in DOE's Second Line of Defense Program, through which we are helping the Russian Customs Service install detection equipment to intercept illicit traffic in nuclear materials at Russian border crossings and checkpoints.

We have also developed technologies to improve the physical security of sites in the U.S. that contain nuclear material or other top-priority assets. A sophisticated, computerized security system called Argus was designed, engineered, and installed at Livermore. Argus is now being installed at other DOE facilities (Idaho National Engineering and Environmental Laboratory, Pantex, and Los Alamos) and DoD facilities. In particular, installation of Argus is proceeding on schedule at Los Alamos, and Phase I was completed in September 2002. A key feature of Argus is planned renewal so that the installed systems never become obsolete. To sustain such renewal, we must improve major components in Argus and add new products.

Materials Management. In 1993, the U.S. signed an agreement with Russia to purchase highly enriched uranium (HEU) extracted from Russian nuclear weapons. Under this agreement, the HEU is blended down in Russia to low-enriched uranium (LEU) and then shipped to the U.S., where the LEU is used in making fuel for nuclear power reactors. During the past year, Russia

destroyed some 30 metric tons of HEU. Some 904 metric tons of LEU were delivered to the United States in 2001, providing fuel for about 40 percent of U.S. nuclear power plants.

Livermore provides comprehensive technical support for transparency measures that serve as a technical basis for assuring each government that the other is abiding by the agreement. With funding from the NNSA Office of Defense Nuclear Nonproliferation, our HEU transparency project activities include onsite monitoring using specially designed instrumentation, documentation review, and data analysis.

Closing the Nuclear Fuel Cycle. New approaches are needed to stimulate growth in the use of nuclear energy in the U.S. Technological innovations offer possibilities for making nuclear reactors inherently more safe and nuclear materials in the fuel cycle more resistant to misuse. Waste management is a particularly pressing concern associated with future nuclear deployment. Both nationally and internationally, closing the back end of the fuel cycle is a critical need. Nationally, advanced fuel-cycle technologies are being explored in parallel with repository disposal (Yucca Mountain Program).

Among other activities, current projects in this area include support of the DOE Nuclear Energy (DOE/NE) Advanced Accelerator Applications Program and development of long-term fuel cycle sustainability criteria for the DOE/NE Gen-IV Reactor Roadmap. These are multilaboratory efforts. In addition, we are working on some international projects, such as performing waste package performance assessment studies for Japan's Nuclear Cycle Development Institute and supporting the DOE-Minatom Spent Fuel Working Group.

3.1.2 Energy, Carbon, and Climate

Situation and Issues

Energy Alternatives and

Transportation. The need for clean, reasonably priced, reliable energy calls for new exploration, production, and utilization methods for hydrocarbon fuels. The Laboratory's strengths in earth and environmental sciences, materials science, engineering, and computational modeling will be applied to develop more efficient combustion, energy storage and conversion, and renewable resources. We are also pursuing emission separation and sequestration technologies (discussed below) and fusion energy science as a possible longer-term source of energy (see Section 3.3.1).

In 2000, the U.S. imported 57 percent of its petroleum—about the amount that the U.S. uses for transportation—and the net imports are expected to increase to 67 percent by 2020. Continued increases of oil imports have important national security implications. In addition, transportation systems are a leading contributor to greenhouse gases and increasingly will be targeted for CO₂ emission reductions. About 30 percent of the global CO₂ emissions from fossil-fuel stems from the use of oil for transportation. Livermore's expertise and programs in advanced materials, systems modeling, alternative transportation fuels (e.g., hydrogen and natural gas), and energy conversion and storage (e.g., fuel cells for mobile applications) provide the basis for expanded work in this area.

In addition, the Laboratory is performing cutting-edge computer simulations of the combustion of fuels in activities that complement the experimental results at Sandia National Laboratories' Research Center in Livermore. Livermore is also

contributing to the Integrated Vehicle Electronics Simulations Testbed (InVEST) Program and other partnerships to develop next-generation vehicles through both simulation efforts and technology development.

Carbon Management. Carbon-based fuels will remain the primary energy sources for the coming decades, with fossil-fuel-derived energy (coal, natural gas, and oil) comprising more than 80 percent of our nation's total energy consumption. Continued use of carbon fuels may increase carbon dioxide levels in the atmosphere with possible environmental consequences. The Laboratory is applying its computational resources to assess the character of these possible environmental consequences and to identify climate-change influences on the storage and movement of carbon through the Earth's land, ocean, and atmospheric systems (see Global Climate Change, below).

The Laboratory is also addressing carbon management through improved technology. Three strategies are being advanced: (1) Movement to lower-carbon fuels, e.g., using natural gas instead of coal or petroleum and enabling the use of manufactured low-carbon fuels such as methanol, liquefied natural gas, and hydrogen. This strategy also includes the development of carbonless electricity production. (2) Improvement in the energy efficiency of all use sectors, including utilities, transportation, industrial, and residential. (3) Development of low-cost separation and carbon-sequestration technologies.

Global Climate Change. A grand challenge that faces the international scientific community is determining the record of Earth's climate over recent centuries and assessing whether humans significantly affect global and regional

climate. As a major contributor to the international global climate modeling effort, Livermore supports DOE's mission to understand the environmental consequences of fossil-fuel use by capitalizing on the Laboratory's strengths in atmospheric sciences and the application of terascale computing to simulation science (e.g., climate models). The Laboratory's unclassified terascale computing resources complement and augment investments from NNSA's Advanced Simulation and Computing (ASCI) Program.

The National Energy Policy recommends "that the President direct federal agencies to support continued research into global climate change." Livermore is a key participant, along with several other national laboratories in DOE's Climate Change Prediction Program and its Accelerated Climate Prediction Initiative (ACPI). The goal is the development of next-generation climate model capabilities that include advances in computational structure and scientific capabilities. Livermore provides leadership in a number of areas including parallelized implementation and optimization of new dynamic cores, creation of an interactive ozone (i.e., non-greenhouse gas) chemistry capability, and analysis of very high-resolution climate simulations.

In addition, Livermore has major responsibilities for the Program for Climate Model Diagnosis and Intercomparison (PCMDI), which was established at the Laboratory in 1989. PCMDI's principal mission is to develop improved methods and tools for the diagnosis, validation, and intercomparison of global climate models and to engage in research on a variety of outstanding problems in climate modeling and analysis. (For an overview of the intercomparison projects

currently under way, see <http://www-pcmdi.llnl.gov/>.)

Program Thrusts

Fossil and Geothermal Energy.

Through 2050, most of our energy requirements will be supplied by fossil energy. We need to develop technologies to enhance the recovery of oil and gas (currently two-thirds of the oil is left in the ground). The Laboratory participates in DOE's Natural Gas and Oil Technology Partnership, an alliance that combines the resources and experience of the nation's petroleum industry with the capabilities and technologies of the national laboratories. This integration expedites development of advanced technologies for better diagnostics, more efficient drilling, and improved natural gas and oil recovery. The Laboratory is engaged in a wide range of projects in the Natural Gas and Oil Technology Partnership in the areas of diagnostic and imaging technology (e.g., seismic profiling); oil and gas recovery (e.g., borehole electromagnetic imaging and fluid injection); drilling, completion, and stimulation technology (e.g., advanced tiltmeter hydraulic fracture imaging); and a variety of computational projects.

We will also explore other technologies that can lead to significant, large-scale innovations in energy production or that can help manage carbon emissions. These efforts build on the Laboratory's strengths in materials, instrumentation, and computational modeling. For example, the potential uses of methane hydrates are so numerous that we must thoroughly understand them. We have conducted preliminary laboratory studies on CO₂ and CH₄ clathrates and are looking to expand these efforts to understand the engineering consequences of recovery options.

Fuel Cells and Energy Conversion.

There are clearly increasing demands for electricity production distribution with particular need for reliable, grid-independent, distributed power from sources that are environmentally clean. We are exploring gas separation technologies, high-power flywheel development, advanced fuel cells, hydrogen infrastructure issues and associated technologies, and advanced sensor, diagnostics, and materials technologies.

Our solid oxide fuel cell (SOFC) technology set a record for the highest energy density of all available fuel cell technologies—over 1 W/cm². We have licensed the SOFC technology and are pursuing a Cooperative Research and Development Agreement (CRADA) with industry. In addition, we demonstrated doubling of the power density for a direct carbon fuel cell with an improved air cathode. More than 100 mW/cm² was achieved using low-cost carbon blacks produced via hydrocarbon pyrolysis. This technology may provide dramatic breakthroughs in clean, high-efficiency utilization of carbon fuels.

In our hydrogen program activities, we demonstrated that thermal cycling does not degrade the performance or safety of our cryotank for hydrogen storage. (The February 2002 cover of *Mechanical Engineering* magazine featured the Laboratory's cryotank design.) We also initiated development of a new solid-state electrolyzer for economical, distributed hydrogen production, and we licensed our Natural Gas Assisted Steam Electrolyzer (NGASE) technology to industry.

Fuel Combustion and Transportation Technologies. Our combustion technology work—focused on advanced computer simulations that complement experimental work at Sandia/

California—will help to improve the cost and efficiency of energy utilization in automotive applications. To enable better simulation of diesel combustion, we extended detailed chemical kinetic mechanisms to hydrocarbons, and we developed kinetic mechanisms for alternative fuels for potential soot reduction in diesel engines. We also established kinetic criteria for ignition in engines and for detonations.

The Laboratory developed a three-year plan for an Integrated Vehicle Electronics Simulation Testbed and performed a co-simulation proof-of-concept demonstration with DOE funding and industry support. This work on improved vehicle systems will help reduce the environmental effects of energy use in transportation.

Finally, our Inductrack technology was chosen for a one-mile deployment in downtown Pittsburgh, Pennsylvania, in a unique demonstration of full-scale use of Laboratory-developed magnetic levitation techniques. The Federal Transit Administration's contractor, General Atomics, is in the process of licensing this technology for much broader industrial and public deployment.

Terascale Model Development—Global to Local Scales. Our goal is to be a leader in developing and integrating predictive atmosphere–ocean models on a global-to-local scale. Using coupled atmosphere–ocean simulation codes integrated with (possibly real-time) data from satellites and other sensor systems, we are striving to achieve unprecedented prediction, speed, and accuracy in climate, weather, and atmospheric dispersion modeling.

We are working to develop more accurate climate, chemistry, and weather forecast models, including the application of high-resolution global

models to study regional-scale phenomena. Through predictions and measurements on a regional scale, we can observe and better understand the potential effect of human activities on global climate. Better climate, chemistry, and weather models require an improved understanding of the relationships among the atmosphere, ocean, and land systems. Use of these models will facilitate responsible environmental management, reliable climate predictions, and anticipation of and effective response to natural and terrorist environmental emergencies.

Laboratory researchers are improving global models by expanding the scope of simulations (e.g., coupling models of the atmosphere and ocean and, ultimately, the carbon cycle) and improving parametric models of chemical and physical processes. For example, we delivered the next-generation National Aeronautics and Space Administration (NASA) Global Modeling Initiative (GMI) Stratospheric Chemistry Model and completed the first 35-year, three-dimensional ozone trend simulation.

One area of considerable effort is the application of global climate simulation models to the Laboratory's large-scale parallel computers, thereby increasing the simulation complexity and enabling simulations at unprecedented resolutions. We completed the world's highest spatial resolution Atmospheric Model Intercomparison Project (AMIP) global climate simulation using the Laboratory's terascale simulation capabilities. These pioneering calculations pave the way toward global climate-change simulations that explicitly include regional effects. PCMDI also completed a detailed set of performance diagnostics for several alternative configurations of the National Center for Atmospheric Research

(NCAR) next-generation climate model. These assessments were instrumental to NCAR's process for selection of the final version, which will become the next state-of-the-art climate prediction model. As an adjunct to these efforts, we are developing better methods for managing and visualizing the vast amount of data generated.

Coupled Climate and Carbon Modeling. Through the Integrated Climate and Carbon Cycle Initiative (INCCA), we are developing a simulation capability that interactively couples climate and carbon-cycle models. Progress on INCCA will depend on effective collaborations with many partners and continuing support from DOE, NASA, and other sponsors. In coupling the oceans and atmosphere with the carbon cycle, we must improve models of subgrid-scale (unresolved) processes, such as local air–sea material and energy exchange and mixing and sea-ice thermodynamics. It is through atmosphere and ocean biochemical and terrestrial ecosystem processes that changes in the global and regional environments are most readily manifested. These changes are both the best diagnostics and the most important effects of global climate changes. Eventually, our models must couple all of these processes at all of the relevant scales—a daunting challenge.

Ocean Carbon Sequestration. Carbon dioxide (CO₂) emissions from fossil-fuel use may adversely affect global climate. The oceans naturally absorb about one-third of the carbon dioxide from human-caused emissions, but climate change could be mitigated if a way could be found to accelerate the ocean's absorption of carbon in an environmentally acceptable way. To develop the scientific base needed to make technical and policy decisions, we are leading efforts to

numerically simulate ocean carbon sequestration. We have performed the highest-resolution simulations to date of direct injection of fossil-fuel carbon in a three-dimensional ocean general circulation model. We are also developing criteria to identify subsurface geologic formations useful for sequestration.

Geologic Sequestration of Carbon Dioxide (GEO-SEQ). About 40 percent of the 1.5 billion tons of U.S. carbon emissions resulting from energy consumption are from power generation plants, principally those that are coal fired. These point-source emitters provide an opportunity to capture and sequester carbon dioxide at suitable local or regional geologic sites. Some underground geologic formations have structure, porosity, and other properties that make them ideal CO₂ storage sites. These are structures that have stored crude oil, natural gas, brine, and CO₂ over millions of years.

The GEO-SEQ project has been established to investigate safe and cost-effective methods for geologic sequestration of CO₂. The project is a public-private research and development partnership that is led by Livermore, Berkeley, and Oak Ridge national laboratories and involves the participation of other laboratories, universities, and petroleum industries. Targeted tasks address (1) siting, selection, and longevity of optimal sequestration sites; (2) lowering the cost and risk of geologic storage and decreasing implementation time; and (3) identifying and demonstrating cost-effective and innovative monitoring technologies to track migration of CO₂.

3.1.3 Environmental Risk Reduction

Situation and Issues

Remediation Technologies and Risk Assessment. Livermore's recent

innovations in remediation technology and tools to assess the health risk from low-level exposure to toxic materials can be used to significantly reduce the national mortgage of environmental cleanup. In a demonstration of an innovative remediation technology in Visalia, California, more than 150,000 gallons—about 1.2 million pounds—of toxic chemicals were removed in the first 30 months of operation. The work was executed by Southern California Edison, with consulting assistance from Livermore and the University of California. The technology used at Visalia—combining dynamic stripping and hydrous pyrolysis/oxidation—is in the process of commercialization. The technology is now being used for cleanup at Portsmouth, Ohio, and Cape Canaveral, Florida.

The Visalia cleanup activities demonstrate end-to-end capabilities at Livermore: understanding the underlying science, developing and applying state-of-the-art simulations, assessing environmental risks and potential clean technologies, and developing and deploying field-scale systems. Moreover, Livermore offers a portfolio of characterization, assessment, control, and remediation technologies demonstrated through work with industrial partners. For example, we have shown that we can characterize a distal underground plume and pull the plume back by using pump-and-treat techniques.

In addition, we have advanced capabilities to assist in risk assessment. For example, the Laboratory manages for DOE the Vadose Zone Observatory (VZO), a unique field-scale facility for studying the physics and chemistry of transport in the vadose (or unsaturated) zone. The VZO consists of instrumented boreholes and monitoring

wells that traverse the unsaturated zone. Instrumentation includes electrical resistance tomography arrays, multilevel gas-sampling ports, soil temperature sensors, gypsum blocks, tensiometers, and lysimeters and wells for electromagnetic induction tomography and water table sampling.

We are also using accelerator mass spectrometry to assess the effects on human health of carcinogens at realistic exposure levels in the environment. This science and technology can greatly improve the effectiveness of remediation strategies in reducing health hazards.

Emergency Response Capabilities.

Livermore has assessment and effective response capabilities needed to deal with a wide range of natural and man-made risks and disasters that pose threats to the environment and international security. With atmospheric modeling capabilities, terascale computers, and national security access and responsibility, Livermore is poised to develop the nation's premier capability for atmospheric dispersion prediction and emergency response on all critical time scales and space scales around the globe.

The National Atmospheric Release Advisory Center (NARAC) is located at Livermore, and we are responsible for the Atmospheric Release Advisory Capability. NARAC is a formally recognized national emergency response service for real-time assessment of atmospheric releases involving nuclear, chemical, biological, and natural hazardous materials. NARAC's primary function is to support DOE and DoD in the event of radiological releases. Under the Federal Radiological Emergency Response Plan, NARAC staff members also assist other federal agencies and support (with DOE approval) local, state, and international agencies' responses to natural and anthropogenic

releases. Since 1979, NARAC has supported more than 1,000 exercises and responded to more than 100 incidents involving radiological and chemical releases, smoke from fires, and plumes from volcanic eruptions. Recent examples include the Cerro Grande Fire at Los Alamos and the September 11 terrorist attacks.

Program Thrusts

Basic Research on Environmental Cleanup. To reduce the cost of environmental cleanup and make it faster over the long term, DOE is sponsoring projects in basic science related to environmental management through its Environmental Management Science Program. In grants from the program, our work ranges from molecular geochemistry to a large-scale look at contaminant movement at the Livermore site. Through several projects, we are studying the movement of contaminants in the vadose zone, a region between the surface and the water table that protects the water from surface contaminants. Livermore researchers are also developing improved computer algorithms and measurement capabilities for subsurface imaging that can be applied to improve environmental management. In addition, we are examining emission-free, high-temperature means for treating and disposing of nuclear wastes that contain actinide elements (including nuclear materials).

These research and development activities are relevant and contribute to projects to remediate groundwater at the Hanford, Savannah River, and Idaho sites as well as the Laboratory's Site 300. We seek to expand our funding from the Environmental Management Science Program by submitting future proposals for pursuing innovative research ideas that build on the

Laboratory's special capabilities and address complex-wide environmental issues.

Radionuclides in the Environment. We are building on our basic research on contaminant movement in the vadose zone, our advanced subsurface imaging technologies, and our terascale computing expertise to greatly improve capabilities to characterize and mitigate in situ radionuclide contaminants. A better understanding of subsurface science—together with improved measurement and simulation tools—will help guide environmental management decisions and validate long-term environmental compliance. Moreover, improvements in characterization and mitigation techniques offer the possibility of dramatically reducing the cost and time required to control radioactive contamination and achieve closure of contaminated DOE contractor sites.

For example, with the aid of laboratory experiments and multicomponent reactive transport modeling, Laboratory researchers explained the enhanced migration of cesium below the Hanford tanks. In addition, Livermore-developed electrical resistance tomography has been selected as one of the candidate technologies to monitor for tank leaks at Hanford. A Livermore team also successfully completed reports describing the migration of radionuclides away from (and thus the environmental consequences of) the Cheshire test on Pahute Mesa and the hydrologic source terms at the Nevada Test Site's Frenchman Flat, which can be used for calculating contaminant boundaries and risk analysis.

Faster Remediation Technologies. To reduce environmental cleanup costs within DOE and nationwide, we will develop and implement accelerated

remediation technologies, which will reduce the cost of cleaning up subsurface contamination and allow land to return to productive economic uses more quickly than with previous methods. Our strategy will be to target DOE, DoD, and civilian contamination problems as opportunities for technology development and application. To validate the performance and the economics of our technologies for other federal and commercial cleanup sites, we will continue building working relationships with industry and regulators on small and large scales and develop the engineering and economic bases for advanced remediation technologies.

Improvements to NARAC. NARAC functions as an integrated research, development, and operational program at the Laboratory. We continue to modernize NARAC's capabilities to better meet the needs of current and potential customers and facilitate services to them. In particular, national security concerns have expanded beyond the nuclear threat to include chemical and biological releases. Potential NARAC applications range from accident response to countering terrorism threats.

The Laboratory is coordinating NARAC research efforts with NNSA's Chemical and Biological National Security Program (which has been transferred into the Department of Homeland Security). We are developing the capability to predict the fate of chemical or biological releases both outdoors and indoors (for example, in buildings and subways). Our focus is on the prediction of airflow and dispersion in difficult-to-model urban environments. These efforts entail the development of a NARAC interface to Livermore's very high-performance computers to provide real-time local meteorological and dispersion forecasts,

detailed vulnerability and mitigation assessments, and accurate predictions of the dispersion and fate of chemical or biological agents released into a complex urban environment. Our goal is to develop the capability for planning, training for, and ultimately, assessing emergency responses to urban chemical and biological releases.

A suite of models has been developed at the Laboratory that incorporates urban area physical effects into the simulation of atmospheric flow and hazardous materials dispersion, and these models were validated against data from field experiments in Salt Lake City. The simulations show that it is both necessary and feasible to include explicit urban physical effects into dispersion predictions.

We have also developed a suite of Internet-based tools that provide increased accessibility of NARAC products to current and potential future users. This tool set allows a range of time-critical emergency response information products to be quickly and efficiently distributed to multiple clients and for clients to interactively engage NARAC operations. In an important application of these new capabilities, the Laboratory is working with agencies in the Seattle area to evaluate the effectiveness of an approach to emergency preparedness that offers the potential for dramatically improving local response capabilities. Sponsored by NNSA's Chemical and Biological National Security Program, the Local Integration of the National Atmospheric Release Advisory Center with Cities (LINC) integrates NARAC's capabilities with local emergency management and response centers (Section 2.2.2).

Center for Accelerator Mass Spectrometry. The Center for Accelerator Mass Spectrometry (CAMS) continues to be a scientific leader in the accelerator mass spectrometry field. It is the most reliable, most versatile, and most productive facility of its kind in the world. During the past year, CAMS produced approximately 29,000 analyses for a suite of nine different isotopes—more than the other three national AMS facilities combined.

As an example of the facility's versatility, CAMS is also a world leader in the application of AMS to biomedical science. In 1999, we received a five-year grant from the National Institutes of Health to serve as a National Research Resource, as a result of long-term CAMS collaborations with Livermore's Biology and Biotechnology Research Programs (BBRP) Directorate and the biomedical community.

Marshall Islands Program. The Marshall Islands Dose Assessment and Radioecology Program is funded by the DOE Office for International Health Programs. The program mission is to provide measurement data and dose assessments to characterize radiological conditions, and to help minimize exposures to resettled and resettling populations. This is achieved through environmental and individual radiation protection monitoring, dose/pathway analysis and dose assessments, and scientific and technical assistance in support of specific resettlement activities.

Current research efforts are focusing on the determination of the environmental half-life of cesium-137 in island soils because this parameter has an important influence on predicted doses to resettling populations.

3.2 Bioscience and Biotechnology

Bioscience research was initiated at Livermore in 1963. Since that time, the program has undergone a dramatic revolution in scope evolving from its initial mission of understanding the biological consequences of ionizing radiation from weapons testing to a modern-day program in molecular biology, genetics, computational biology, biotechnology, and health-care research. Today, we conduct basic and applied research in the health and life sciences in support of national needs: to understand causes and mechanisms of ill health, develop biodefense capabilities for national homeland security, improve disease prevention, and lower health-care costs. Our vision statement, "Enhancing the nation's health and security through technological innovation in the biosciences," reflects our dedication to apply our acquired knowledge of science and technology to address societal needs.

Today and in the future, research activities in biology, biotechnology, and health care fit well into a technology-rich, multidisciplinary, broad-based national laboratory. The core program in biosciences is multidisciplinary, drawing upon Livermore's matrix organization in physical sciences and engineering. Many bioscience staff are physicists, chemists, engineers, mathematicians, and computer scientists who come from the diverse laboratory infrastructure and who work side by side with the core biologists and biochemists. The cross-fertilization of talents provides our bioscientists access to the latest technologies in physical sciences and engineering, which are inherent in the

parent discipline organizations.

Conversely, bioscientists at Livermore make significant contributions to national security activities and other major programs at the Laboratory. This important “spinback” to the Laboratory’s defining mission increases the benefits to the nation of sustaining a strong bioscience and biotechnology program at Livermore.

Grand Challenges in the Biosciences.

BBRP has been reorganized into six scientific areas that reflect research important to the missions of DOE and the Laboratory. These thrust areas and ensuing challenges are based upon a set of core competencies that provide the foundation for the Laboratory-wide strategic plan in the biosciences.

- **Health Effects Genetics:** to develop and apply novel, genomic-based approaches for measuring and understanding cellular and tissue effects of low-level radiation and chemical exposures, with links to clinical medicine and risk assessment.
- **Genome Regulation and Function:** to develop and apply genome-scale approaches to understand the function, regulation, and evolution of genes in complex genomes.
- **Molecular Biophysics:** to develop and apply tools that measure biochemical and cellular components and processes, emphasizing data that support predictive understanding through complex simulation and modeling.
- **Computational and Systems Biology:** to combine advanced simulations with new experimental data sets to develop a predictive understanding of biological processes, ranging from biochemical mechanisms to cellular behavior.
- **Biodefense:** to provide underpinning science and tools needed to render bioterrorism ineffective.

- **Environmental Microbiology:** to provide scientific leadership in bringing “biology of scale” to microbial biology and apply this knowledge to DOE missions in energy, security, and environmental protection and restoration.

Bioscience and biotechnology research at Livermore is supported by diverse sources. Support from the DOE Office of Biological and Environmental Research (OBER) is about 40 percent of the overall budget. The office supports major research efforts at Livermore as well as Joint Genome Institute activities at our Walnut Creek location. The DOE Office of Non-Proliferation and National Security (ONNS) provides an additional 30 percent of the BBRP budget. Over the past year, Livermore has continued its leadership role in countering bioterrorism. We have worked closely with DOE and other national laboratories, particularly Los Alamos, to develop a strategic plan for biological research in support of biodefense. The focus remains on serving the needs of DOE/OBER and DOE/ONNS and developing with them new program opportunities.

Additional support comes from sources such as the National Institutes of Health (NIH), other government sources, and industry. NIH is expected to continue its role as the major funding source for bioscience research in the United States. Funding from NIH and other peer-reviewed sources is essential for Livermore bioscientists to maintain credibility with their peers. For example, with joint funding from NIH, bioscience researchers from Livermore and the University of California at Davis Medical Center form a designated National Cancer Institute

Comprehensive Cancer Center. With funding from multiple sources, Livermore serves DOE missions while applying the Laboratory’s special science and engineering skills to meet important needs of a variety of sponsors.

3.2.1 Health Effects Genetics

Situation and Issues

Mechanisms of Exposure.

Understanding the potential health risks of human exposure to chemicals and radiation is an effort with important and wide-ranging implications for human health. In this regard, we have focused our research on exposure mechanisms and on processes of DNA repair, mutagenesis, and carcinogenesis as well as reproductive and developmental toxicity. Much of our work encompasses the development and validation of biomarkers in animal models that are indicative of the damage caused to somatic and germinal tissues. A significant emphasis is also placed on understanding the mechanisms of these processes so that the implications derived from animal models can be better related to human health.

Program Thrusts

DNA Damage and Repair. We have put considerable effort into understanding the mechanisms and variability of the repair of DNA damage. The genes and proteins responsible for single base excision of damage, larger base excisions (nucleotide base excision repair), and recombinational repair have been studied extensively. Human polymorphisms have been identified in most of the pathways and genes involved in these processes. The role of these genetic variations on the enzymatic

activity and, ultimately, the susceptibility to cancer and disease are being evaluated. We are developing new ways to study these processes (repair, adducts, and mutations) directly in humans so that dose-response models can be developed to incorporate the genetic variability of the human population into risk characterization.

Gene Characterization. Another focus of research in disease susceptibility and prevention is the relationship between an individual's genes and disease. Cancer and other human diseases are often caused by defective proteins or damage produced by radiation or molecules that bind to and alter DNA. Our goals are to identify genes that control individual susceptibility (with emphasis on DNA repair genes), understand how the associated proteins are involved in the disease process, assess human variability for these genes, and estimate risk for disease on the basis of an individual's genetic constitution. We will couple this research to genomic approaches, which should expedite rapid discovery. A technique known as rolling circle amplification (RCA) has been adapted by Livermore scientists over the past year to allow researchers to determine gene copy number and to detect single base mutations in individual cells in situ as well as to quantify gene expression in single cells. A special focus will continue to be risk assessment of ill health from adverse exposure to radiation and chemicals, either directly through human studies or through cellular and animal data.

In another long-standing focal area—health effects genetics—we will continue to develop and apply novel, genomic-based approaches to measuring and understanding the cellular and tissue effects of low-level radiation and chemical exposures. We

will link those exposures to clinical medicine and risk assessment.

3.2.2 Genome Regulation and Function

Situation and Issues

Genomics Research. Genomics is a multidisciplinary science whose goals are to characterize the genetic material of mammalian, plant, and microbial species. With gene sequencing largely completed and other capabilities advancing rapidly, we are approaching the “post-genomic” era, the goals of which are to develop and apply genome-scale approaches to understand the function, regulation, and evolution of genes in complex genomes. We are studying genome organization by examining the interposition of genes with structural and regulatory elements in DNA, identifying genes, and predicting proteins they produce. In addition, we use comparative genomics (cross-species analysis) to study evolution, gene function, and human disease.

Comparative Sequence Analysis.

During 2001, DOE's Joint Genome Institute (JGI)—comprising staff from Berkeley, Los Alamos, and Lawrence Livermore national laboratories—continued to draft and finish the DNA sequence for human chromosomes 5, 16, and 19. In the next year, the three chromosomes are due to be completed, and their analyses will be published. As a part of JGI within the larger International Human Genome Program, we have collaborated on two landmark reports in *Nature*, “Initial Sequencing and Analysis of the Human Genome” and “A Physical Map of the Human Genome.” Also in 2001, *Science* published our work comparing human chromosome 19 DNA with related regions in mouse, which provides the

first clues to the mechanisms of gene and chromosome evolution in mammals. We also are working with universities and other research institutions to provide a comprehensive public collection of complementary DNA (cDNA) clones. The DOE-sponsored I.M.A.G.E. Consortium, based at Livermore, includes over 5 million arrayed clones, 2.5 million sequences, and over 50,000 mapped cDNAs.

For the long term, we believe that extracting biologically and functionally relevant information from sequence data should be a focus of work at Livermore. This effort includes comparative sequencing, cDNA and protein characterization, computational data mining, and understanding the relevance of human polymorphisms.

Program Thrust

The goals of this genomic research area at Livermore are to develop and apply genome-scale approaches to understand the function, regulation, and evolution of genes in complex genomes. Subtechnologies include physical mapping, DNA sequencing, gene discovery, subtractive hybridization, computations and informatics, diagnostics, and automation and robotics. Traditional genomics resources, including the sequencing capability at the JGI and the I.M.A.G.E. Consortium cDNA collection, continue to be valuable tools for this research.

Tools to Study Genes. We specifically focus on the development and application of genome-scale approaches to understand gene function, regulation, and evolution in complex organisms. We rely on the multidisciplinary capabilities available to us, such as sequence data generated at the Joint Genome Institute, data analysis from Livermore's unique computing and bioinformatics capability,

model systems development such as mouse for investigating disease-related functions of human genes, and comparative genomics approaches for understanding genome evolution and regulatory networks. Livermore contributes to the future of JGI and DOE's post-genomics program by developing new technologies and strategies for functional genomics. They include methods for measuring gene expression, experimental and computational tools for human and microbial sequence annotation, and protein-folding prediction tools—the first steps toward understanding the components of gene regulatory pathways from microbes to humans.

3.2.3 Molecular Biophysics

Situation and Issues

Understanding Proteins and

Pathways. Understanding how proteins function is an important next step toward interpreting the data obtained from the Human Genome Project. Protein characterization includes the expression of proteins; generation of expression arrays; study of protein–DNA, protein–protein, and protein–small molecule interactions; understanding of pathway dynamics such as intracellular transport or cell-to-cell signaling; and structural characterization of individual proteins and protein complexes. The Laboratory's capabilities for measuring and modeling proteins and pathways must be tightly linked to specific scientific questions.

Program Thrust

Development of Tools. The goals of this focus area are to develop and apply tools based on Livermore capabilities in physical, chemical, and engineering sciences to measure biochemical and

cellular components and processes. Our emphasis is on generating data to support predictive understanding of the biological world, including the use of complex simulations and modeling. We use tools such as accelerator mass spectroscopy, x-ray crystallography, nuclear magnetic resonance (NMR) spectroscopy, and high-throughput protein production technologies. For our own use and that of the international scientific community, we maintain a protein structure prediction center, a state-of-the-art crystallography facility, and an NMR facility for research on macromolecular interactions and variation.

We plan to extend our capabilities, using tools such as molecular-level diagnostics of genetic and biochemical processes involved in cellular function and communication, single molecule structural measurement using fourth-generation light sources, and inter- and intracellular chemistry involved in the functions of biochemical pathogens and signaling.

3.2.4 Computational and Systems Biology

Situation and Issues

Advanced computational techniques permit bioscientists to “see” inside biochemical processes to learn how reactions are taking place on a molecular level, tying computational models to experimental research. Our researchers are at the forefront of integrating computation and experiments in bioscience. They use simulation methods ranging from molecular dynamics that use classical laws of physics to first-principles methods that use quantum mechanics to exactly describe the electronic structure of every atom.

In the past year, our scientists have used computational modeling to predict

the structure and function of several newly identified virulence factors in *Yersinia pestis*, the causative agent of plague. These results provide a starting point for experimental studies to elucidate the virulence mechanisms of this important pathogen. We have also identified potential binders for several proteins, including the botulinum-A neurotoxin.

Program Thrusts

Livermore's capabilities in computational biology are recognized by the scientific research community, as shown by growing numbers of requests for invited talks, review articles, and textbook chapters and for new collaborations with universities and companies.

Modeling DNA. Our principal focus has been DNA-related molecular biology, including the properties of DNA-damaging drugs and environmental mutagens, the structure and dynamics of damaged DNA, and the proteins and protein complexes that repair and replicate DNA. Several new collaborative research projects are also under way, such as developing new therapeutics with the UC Davis Cancer Center and detecting bacterial toxins for our Laboratory's nonproliferation programs.

Predicting Protein Structure. The protein structure prediction efforts include providing community-wide resources, such as the Critical Assessment of Structure Prediction competitions held every two years and the development and application of structure prediction methods for Livermore biology projects. Using the latest and most precise technologies and computer models, we are applying first-principles molecular dynamics simulations to study simple biochemical reactions. These calculations, which

require Livermore's unique massively parallel supercomputing capabilities to simulate a few hundred atoms for a few picoseconds, yield the most precise results within these size and time-scale constraints compared with other models.

Taking advantage of the unique opportunity to combine the advanced computing power available at LLNL with new experimental data sets, we will continue to develop a predictive understanding of biological processes, ranging from biochemical mechanisms to cellular behavior.

3.2.5 Biodefense

Situation and Issues

During the past decade, substantial concerns worldwide have developed about the potential for acts of biological terrorism and biological warfare. In October and November of 2001, the anthrax attacks in Florida, New York, and Washington, D.C., highlighted our nation's vulnerability to such an attack. They also accentuated the public's fear of additional similar events. Livermore continues at the forefront of biodefense tool development, working with other national laboratories and institutions to reduce the threat of biological weapons and bioterrorism.

Program Thrusts

Microbial Studies. We couple our technologies and competencies in national security (biological nonproliferation and counterterrorism) with those in the biological sciences (microbial genetics, enzymology, and genomics) and engineering (microfabricated bioinstruments). We continue to develop applications relevant to national security, including the detection and biological signature

analysis of samples collected from air, soil, and water. Research has been dedicated to developing DNA-based assays for pathogens of concern for both detection and forensic purposes. To develop reliable assays, we must have an extensive foundation of biological knowledge, such as understanding of the phylogenetic relationships among neighboring organisms, the capability to generate sequence data for the pathogens and their neighbors, understanding of virulence mechanisms, and the capability to develop well-characterized strain collections. Automated approaches for scale-up, miniaturization, and multiplex analysis are important to these methods.

Technology Development. A major focus of the DOE and Livermore biodefense programs is on developing better detection capabilities for biological agents. A particular focus is on small, portable equipment that can rapidly perform polymerase chain reactions (PCR) for organism detection. Our seven-minute PCR capability (first reported in *Science*, 1999) provides the basis for a series of instruments to detect and characterize biological pathogens, now used by multiple agencies. A handheld PCR unit, based on a Livermore design and suitable for first responders, is now in commercial production. A "bio-smoke detector," called the Autonomous Pathogen Detection System, has been shown to be highly effective in detecting releases in an around-the-clock mode.

A relocatable field laboratory was assembled in 2000 and tested during 2001 to put biodetection tools into the field in a timely fashion. This system, a joint effort of Lawrence Livermore and Los Alamos national laboratories, was deployed in fall 2001 and in Salt Lake City for the 2002 Winter Olympics.

3.2.6 Environmental Microbiology

Situation and Issues

The field of environmental microbiology stands to benefit greatly from the technological advances of the genomics revolution. We will apply knowledge gained in this area, especially in sequencing and gene and protein analysis, to DOE missions in energy, security, and environmental protection and restoration.

Program Thrust

This is a new thrust area for the Laboratory, which will bring "biology of scale" to the field of microbial biology. Our specific aims include performing genome-scale analysis of microbial functions to understand the biochemical pathways involved in core functions and applying the knowledge gained to problems of energy production, carbon emission control, and environmental cleanup.

3.3 Fundamental Science and Applied Technology

One of DOE's primary missions is to pursue fundamental science and provide capabilities that enable the U.S. to maintain its world leadership in science. The Department must also advance the science and technology that is required to support DOE's primary missions in national security, energy resources, and environmental quality. It is widely recognized that the nation's advances of fundamental knowledge and technological innovation provide the U.S. an advantage in an increasingly competitive world.

The pursuit of fundamental science and the advance of applied technology go hand in hand at Livermore. State-of-

the-art applied technology is used to advance fundamental science in areas pertinent to the Laboratory's major missions. In some cases, the work is sponsored by DOE's Office of Science or other customers who take advantage of the unique research capabilities and facilities present at the Laboratory. In other cases, the work is supported by Laboratory Directed Research and Development funding and extends Livermore's capabilities in support of current and new mission requirements.

Our scientific advances—and technologies developed in pursuit of fundamental science—have important spinoff and spinback applications, such as:

- Livermore-developed adaptive optics technologies that have been installed on the 10-meter-diameter Keck II Telescope on Mauna Kea, Hawaii, to correct for atmospheric turbulence and significantly improve the quality of images—surpassing those from the Hubble Space Telescope. Adaptive optics is also a critical, enabling technology for the National Ignition Facility (NIF). Laboratory researchers also developed a revolutionary technology to apply ultrathin silver coatings to the mirrors in flashlamps for NIF, and it is being used to coat the mirrors and improve the performance of telescopes in observatories around the world.
- The discovery of fluid metallic hydrogen—a new state of matter—which contributes to planetary science and generates new knowledge about the properties of hydrogen that is needed for Laboratory programs.
- Livermore's development of ultrashort-pulse lasers, which enable physics experiments at plasma conditions similar to those inside stars. The lasers also have precision cutting capabilities for

advanced manufacturing in stockpile management and many broader applications in which distortionless processing is required.

- Experiments using Livermore's diamond anvil system to study the equation of state of carbon dioxide at extreme conditions. Researchers have created solid forms of carbon dioxide never before seen in the laboratory, one of which (CO₂-V) has covalent bonds and shows nonlinear optical behavior. The work generated data needed to improve simulation codes for stockpile stewardship and resulted in three papers in *Physical Review Letters* and an article in *Science*.
- Materials synthesis and materials engineering at the atomic level. For example, we have developed ultraprecise grating arrays for spectrometers for the X-Ray Multi-Mirror Newton Observatory and multilayer optics that enable mapping the x-ray spectrum of the Sun in incredible detail.
- Studies, with the U.S. Geological Survey, to understand the equation of state of methane clathrate. The work may lead to future exploitation of methane clathrate as an energy source and of a clathrate from carbon dioxide. In addition, if carbon dioxide proves to be relatively stable as a clathrate in the deep sea or in deep-sea sediments, it could be a promising option for deep-sea carbon sequestration.
- Livermore's participation in the Extreme Ultraviolet Lithography project, along with Sandia/California and Berkeley national laboratories. Critical milestones have been achieved, which make this the technology of choice for computer microchip fabrication over the decade 2005–2015. ASCI computers for the Stockpile Stewardship Program will, in turn, become increasingly powerful.

Science and Technology at the Laboratory

The tight coupling of science and technology at Livermore is reflected in our mission focus and the use of Laboratory Directed Research and Development to prepare for future mission requirements. As discussed in Section 3.4, we depend on effective partnerships with other laboratories, academic institutions, and industry to be successful in our endeavors.

Application of Mission-Directed Science and Technology. As an institution with stable mission responsibilities and program continuity, the Laboratory has developed a strong science and technology infrastructure. We focus our unique capabilities and research facilities on problem solving to meet the demands of DOE's national security mission. This science and technology base also enables us to meet other important national needs and respond to new challenges. These national needs align with DOE's missions in energy resources and environmental quality (see Section 3.1 Energy and Environmental Programs) and in science (Sections 3.2 Bioscience and Biotechnology and 3.3.1 Application of Mission-Directed Science and Technology).

Laboratory Directed Research and Development. We sustain and strengthen the Laboratory's science and technology base through effectively managed internal investments in Laboratory Directed Research and Development (LDRD). LDRD supports research and development (R&D) projects that enhance Livermore's core strengths, expand DOE's and the Laboratory's scientific and technical horizons, and create new capabilities in support of the Laboratory's missions.

Alignment with the DOE Strategic Objectives

The strong interrelationship between science and technology at the Laboratory means that the development of “technology” is integral to our programmatic activities and serves as a principal tool for achieving mission success. By comparison, “science” is a specifically identified DOE mission area, but it also is a tool for achieving success in other DOE missions. Accordingly, some of the Laboratory’s fundamental science activities are supported by DOE’s Office of Science. Other activities—particularly in national security areas—are embedded in programmatic work, and yet other activities are supported by Laboratory Directed Research and Development.

DOE’s science mission is to “advance the basic research and instruments of science that are the foundations for the Department’s applied missions, a base for U.S. technology innovation, and a source of remarkable insights into our physical and biological world and the nature of matter and energy.” Activities at the Laboratory address the four objectives of the science mission (e.g., see *DOE FY 2001 Performance and Accountability Report*):

Objective 1. Provide the leadership, foundations, and breakthroughs in the physical sciences that will sustain advancements in our nation’s quest for clean, affordable, and abundant energy. See Sections 3.1.1 Nuclear Systems and Materials Management and 3.1.2 Energy, Carbon, and Climate.

Objective 2. Develop the scientific foundations to understand and protect our living planet from the adverse impacts of energy supply and use, support long-term environmental cleanup and management at DOE sites, and contribute core competencies to

interagency research and national challenges in the biological and environmental sciences. See Sections 3.1.2 Energy, Carbon, and Climate and 3.1.3 Environmental Risk Reduction.

Objective 3. Explore matter and energy as elementary building blocks from atoms to life, expanding our knowledge of the most fundamental laws of nature spanning scales from the infinitesimally small to the infinitely large. See Sections 2.1 Stockpile Stewardship, 3.2 Bioscience and Biotechnology, and 3.3.1 Application of Mission-Directed Science and Technology.

Objective 4. Provide the extraordinary tools, scientific workforce, and multidisciplinary research infrastructure that ensure success of DOE’s science mission and support our nation’s leadership in the physical, biological, environmental, and computational sciences. This objective is addressed by almost all of our activities. Some of our activities for DOE’s Office of Science are especially emphasized in Section 3.3.1 Application of Mission-Directed Science and Technology.

3.3.1 Application of Mission-Directed Science and Technology

Situation and Issues

Livermore has special capabilities for meeting some of the nation’s broader challenges in fundamental science and applied technology. These capabilities and facilities are a consequence of Livermore’s overall size, the need for technologies and capabilities that do not exist elsewhere, and the fact that essential elements of our national security mission are classified. Much of the expertise necessary to support national security programs resides within the Laboratory. For example, we have capabilities to develop state-of-the-art

instrumentation for detecting, measuring, and analyzing a wide range of physical events. We also have expertise to support innovative efforts in advanced materials, precision engineering, microfabrication, nondestructive evaluation, complex-system control and automation, and chemical, biological, and photon processes.

Program Thrusts

Our special capabilities are being applied to meet the nation’s challenges in fundamental science and applied technology, including:

Astrophysics and Space Science. In partnership with many other scientific institutions, we make important advancements in astrophysics and space science by applying the Laboratory’s special expertise in high-energy-density physics, nuclear fusion, and scientific computing. Livermore researchers participate in a wide range of observational, experimental, and theoretical activities—from the creation of supernova-like instabilities using powerful lasers to the sighting of the most distant radio galaxy and the discovery of a quasi-stellar object with one of the most luminous starbursts ever.

Astrophysics research complements the Laboratory’s important stockpile stewardship responsibilities and applies Livermore’s expertise in high-energy-density physics. For example, there is considerable overlap between the physical data gathered to improve the predictive capability of the Stockpile Stewardship Program and that needed to improve the modeling of astrophysical processes. The Physical Data Research Program at Livermore provides validated physical data for use in simulations of both nuclear weapons and astrophysics. Through a wide range of activities, theory is combined with computer

simulations and laboratory measurements to provide validated opacity and equation-of-state databases.

In addition, researchers at Livermore are developing a three-dimensional stellar evolution model (Djehuty) that runs on massively parallel computers. It uses the best available physical data (e.g., opacities and equations of state). Investigators first used the Djehuty model to investigate a well-characterized discrepancy between the results of one-dimensional stellar models and the behavior of stars, and they are now pursuing the first three-dimensional science study of convective cores in stars.

Livermore also makes important advances in instrumentation, as demonstrated by the development of sensors for the Clementine satellite, which mapped the entire surface of the Moon. This sensor technology has led to other advances, such as development of a revolutionary camera system and its use to discover massively compact halo objects (MACHOs). Our work on adaptive optics has enabled the Keck II Telescope to take images of unprecedented quality of Neptune and Titan. Livermore's multilayer optics are yielding extremely detailed x-ray images of the surface of the Sun, and the Laboratory's ultraprecise grating arrays for spectrometers are enabling the satellite-based X-Ray Multi-Mirror Newton Observatory to take multispectral x-ray images of other galaxies.

Accelerator Technology. The Laboratory contributes to national accelerator R&D programs with its innovative approaches to accelerator design and detector systems and its broadly based capabilities in engineering, precision manufacturing, and multidisciplinary project management. Livermore was part of the

three-laboratory effort that designed and built the B Factory at the Stanford Linear Accelerator Center (SLAC). Working with SLAC and Lawrence Berkeley, we contributed across a broad range of disciplines, ranging from particle physics to precision machining.

As part of an international collaboration that includes the same tri-laboratory team, Livermore is now pursuing research and development for the Next Linear Collider (NLC). NLC would be a 30-kilometer-long facility to explore physics beyond the Standard Model, including the study of the spectra of Higgs particles. The research and development project is patterned after the very successful B Factory collaboration. Livermore is making significant contributions in several areas of linear accelerator (linac) technology to improve system performance and obtain large reductions in project costs. In addition, the Laboratory is applying its unique expertise in high-average-power, short-pulse lasers to study the feasibility of designing a high-luminosity gamma–gamma collider as a second interaction region for NLC (or any other future linear collider). A gamma–gamma collider would open up entirely new physics complementary to the electron–positron collisions.

In addition, Livermore is a charter member of a consortium including SLAC, Los Alamos, and the University of California at Los Angeles that is carrying out research and development toward a demonstration facility, called the Linac Coherent Light Source (LCLS). Advances in low-emittance electron linacs over the past several years have opened up the possibility of unprecedented brightness in a fundamentally new kind of synchrotron light source. A free-electron laser (FEL) consisting of such a linac driving a long

precision-fabricated undulator can produce monochromatic 0.1-nanometer radiation that is 10 billion times brighter than existing “third-generation” facilities such as the Argonne Advanced Photon Source. Livermore is involved in several key aspects of the project, including undulator design, low-emittance electron sources, and novel x-ray optics.

Our accelerator expertise is also being applied to important national security applications, including the development of advanced diagnostic capabilities for hydrodynamic testing. A candidate technology is the use of high-energy protons as the radiographic probe of hydrodynamic tests. We have been working with Los Alamos on the design of a machine and detectors for proton radiography. This design effort has been carried out in collaboration with DOE's High Energy Physics Program at several DOE national laboratories.

Microelectronics and Optoelectronics.

The Laboratory's strengths in microelectronics and optoelectronics help us meet the demands for enhanced surveillance of aging nuclear weapons as well as for advanced diagnostics and precision target fabrication in the inertial confinement fusion program. Our expertise in thin-film processing and microfabrication technology is leading to many applications in lithography, semiconductor processing and process modeling, electronics packaging, communication and computing systems, and biotechnology. Advances have made possible microtools for health care, portable biological agent detectors, and diagnostics for the National Ignition Facility.

Advanced Materials and Materials

Science. Our work in materials science ranges from fundamental research on the properties of materials to the engineering of novel materials at the atomic or near-

atomic levels, research that is often pursued to the stage where the materials can be readily manufactured. Aerogels and nanoengineered multilayer materials developed at Livermore have tremendous implications for new products and future Laboratory programs. Other advances include highly efficient energy-storage components, ultralight structural materials, tailored coatings, and novel electronic, magnetic, and optical materials.

The Laboratory's fundamental research includes work for the Office of Basic Energy Sciences (OBES) currently in 10 project areas spread across metallurgy and ceramics, solid-state physics, and materials chemistry. For example, we are continuing to make important advances in the application of synchrotron radiation to the in situ characterization of welds to develop predictive capability. Our advanced heterointerfaces project has developed a unique tool for unambiguously determining the electronic structure and effects of quantum confinement in nanoparticles. The tool was used to determine the bucky-ball-like surface structure of nanocrystalline diamond. Other projects are in areas such as nanomagnetism, interfaces and grain boundaries and their role in the behavior of metals, and the superplastic deformation of metals and intermetallics.

Through fundamental science research activities, we are improving our understanding of material deformations and radiation effects on materials. In addition, we are working to develop a basic, yet detailed, understanding of the mechanical properties of metals through the development of a multiscale model of metals that is validated by experiments. The goal is to understand dislocation dynamics that affect the strength of materials at the micrometer scale.

Multiscale modeling uses the Laboratory's supercomputers and involves simulations at three length scales (atomistic, micro, and meso) with information passing from the shorter to longer length scales. Our 300-kiloelectronvolt, field-emission transmission electron microscope (TEM) is the best of its kind in the DOE complex. Used to study the internal structure of materials and resolve features at the atomic scale, the TEM is one of the Laboratory's principal experimental tools for studying the properties of plutonium and validating material models.

In addition, Livermore is advancing laser shock peening, a technology to impart deep compressive stresses in metals. This technology has benefits for the Stockpile Stewardship Program, the Yucca Mountain nuclear waste storage facility, and a range of military and industrial high-material-stress applications.

High-Performance Scientific Computing. With the arrival of successively more powerful supercomputers at Livermore through the Advanced Simulation and Computing (ASCI) Program, we have unparalleled capabilities in scientific computing that offer the potential for revolutionizing scientific discovery. Key to their effective utilization are improvements in scientific software, data management, and visualization tools.

Through various collaborative efforts and for sponsors that include DOE's Office of Science, we conduct basic research in computational science in areas that support programmatic objectives. Areas of focus include high-performance computing, computational physics, numerical mathematics, algorithm development, scientific data

management, and visualization. Some of the cutting-edge research conducted on supercomputers at the Laboratory is supported by the Office of Science's Scientific Discovery through Advanced Computing (SciDAC) Program. Last year, Livermore and collaborators received more than \$23 million from SciDAC to study subjects including supernovae, climate modeling, plasma microturbulence, and development of supercomputer simulation tools. The Laboratory is participating in 10 SciDAC projects and leading 2 of them. Continuing involvement with SciDAC will depend on how research funds such as these are allocated between DOE and the Department of Homeland Security.

Fusion Energy Science. Livermore conducts inertial fusion experiments and pursues advanced magnetic confinement fusion schemes using the Omega laser at the University of Rochester and, in the future, the National Ignition Facility (NIF) at Livermore. We seek to identify and make progress along the most promising path to full-scale deployment of fusion power. To establish the scientific basis of energy production from nuclear fusion is a long-standing goal at Livermore. We seek to demonstrate—for the first time in a laboratory setting—fusion ignition and energy gain at NIF, which is now under construction at Livermore.

In our Inertial Fusion Energy (IFE) Program, demonstration of fusion ignition and energy will be conducted in parallel with a research program on fusion driver concepts (ion-beam accelerators and lasers) to meet the efficiency and repetition-rate requirements of inertial fusion power plants. In particular, for DOE's Office of Science, we are working as part of the Heavy-Ion Fusion Virtual National

Laboratory (HIF-VNL) to assess and advance the technology for heavy-ion accelerators as drivers for commercial IFE generation. Initiated in 1998, the HIF-VNL is a coordinated research program of Lawrence Livermore and Berkeley national laboratories and the Princeton Plasma Physics Laboratory. The partners are combining resources to develop three beam experiments: high-current transport, neutralized transport, and ion source development. Central to the Livermore contribution is expertise in ion-beam theory and modeling. In addition, we are also working with the University of Rochester Laboratory for Laser Energetics on advanced technologies for laser drivers. We are also exploring the concept of fast ignition inertial fusion—conventional compression of the fuel followed by ignition with a short-pulse, high-power beam.

Furthermore, building on the considerable long-standing support provided by NNSA Defense Programs, the Laboratory provides leadership in IFE target design. Target physics and design are essential components of IFE, and improvements often translate into relaxation of other program elements. Recent Livermore accomplishments include integrated calculations from energy deposition through burn for heavy-ion designs using two-sided illumination and development of larger beam-spot focal areas by almost a factor of 3, effectively relaxing beam focusing requirements.

In the area of magnetic fusion energy (MFE) research, the tokamak concept has been used to advance the science of high-temperature plasmas. Livermore collaborates in experimental studies centered on advanced performance and power handling for the tokamak using the DIII-D tokamak at General Atomics.

In the DIII-D Program, we have the lead role in the critical area of power handling (and divertor physics in general), and we contribute importantly to the study of advanced operating scenarios.

We are also focusing attention on advanced and alternative plasma confinement concepts, such as the spheromak. The spheromak has an internal dynamo to create its confining magnetic field and is therefore a much simpler and more flexible engineering concept than a tokamak. Livermore has built and is conducting tests using a 1-meter spheromak. The Sustained Spheromak Physics Experiment (SSPX) facility was dedicated in January 1999. In an effort that involves many collaborators, the SSPX is achieving high electron temperatures and generating valuable data to help improve plasma simulation codes. DOE's Office of Fusion Energy Sciences has called the SSPX a "world-class facility," with recent experiments indicating that temperatures of 150 electronvolts have been achieved in the device. Our goal is to understand and optimize energy confinement in the spheromak and, if results are promising, develop a larger follow-up experiment.

In addition, we provide leadership in the use of large-scale simulation of plasmas as a very cost-effective way of carrying out fusion research. Gyrokinetic simulation codes developed at Livermore have been the standard benchmark for other major kinetic and fluid codes that describe plasma turbulence in the core of confinement devices. These include BOUT 3-D, UEDGE, and CORSICA, which couples various computational models (such as power input, heat loss, and magnetohydrodynamic equilibrium and stability) that proceed on different time

scales. CORSICA has been combined with the General Atomics code ONETWO to provide a combined analysis and predictive code called CALTRANS for the DIII-D tokamak. CALTRANS has provided key building blocks and concepts for the National Transport Code initiative.

Finally, Livermore contributes to the DOE Office of Fusion Energy Science's Virtual Laboratory for Technology through the design and testing of magnets for MFE, the investigation of liquid walls for MFE chambers, and studies of neutron damage and advanced materials for fusion reactors.

Laser Science and Technology. The Laboratory has unmatched capabilities in high-energy and high-power solid-state lasers. We will apply this expertise to meet critical needs in national security, energy security, and environmental applications. In addition, we will expand collaborations with industry and other partners to identify laser and electro-optics technologies that can be developed and transferred to the private sector.

One area of attention is the development of high-average-power ultrashort-pulse laser technology and hardware. Before the Nova laser was shut down, the Laboratory successfully developed and operated the Petawatt laser system, which still holds the world's record for the highest pulsed power ever achieved by lasers. One of the critical enabling technologies was the manufacture of large-aperture and high-damage-threshold diffraction gratings. The technology is being applied to the National Ignition Facility, and we have been developing and fabricating large-aperture diffraction optics for Work-for-Others sponsors. A new LDRD Strategic Initiative is looking at even higher damage-resistant

gratings and other key laser and optical technologies that can enable high-energy petawatt (HEPW) applications on the National Ignition Facility and other large laser systems. Researchers are also developing large-aperture lightweight Fresnel lenses for space-based applications.

In addition, Livermore scientists are integrating the Falcon ultrashort-pulse (35-femtosecond) laser with Livermore's linac (with a 100-megaelectronvolt electron beam) to produce a unique ultrafast x-ray source. The objective is to produce ultrashort bursts of tunable hard x rays (greater than 10 kiloelectronvolts) that can be used to make time-resolved measurements of the properties of materials undergoing rapid change. Other efforts are focusing on the development of a laser with an even shorter pulse, which has set a world's record for brightness. The goal is to use this laser (JanUSP) to explore plasma conditions similar to those inside stars and detonating nuclear weapons by extremely rapid heating of small samples of material. The JanUSP effort is benefiting from the Laboratory's development, with support from LDRD, of a new front-end technology for short-pulse lasers—optical-parametric, chirped-pulse amplification (OPCPA), which eliminates the problem of prepulses and greatly reduces amplified spontaneous emission. We anticipate widespread use of OPCPA—in glass-based, petawatt-laser systems and high-average-power systems.

Precision-Manufacturing Technologies. The Laboratory has considerable capabilities in advanced manufacturing technologies, ranging from femtosecond laser machining to precision manufacturing and manufacturing control. For example, the Laboratory is a world leader in precision

engineering and in developing precision manufacturing systems, with technical expertise in a wide range of areas. The Laboratory has invented a number of new metrological devices in response to programs that have needed parts fabricated or measurements made beyond the limits of existing instruments. An example is the absolute interferometer, able to measure errors in the surfaces of optical parts to the thickness of just a few atoms. One of our finest achievements of precision engineering is the Laboratory's Large Optics Diamond Turning Machine, which is the most accurate large machine tool in the world.

Livermore's precision engineering capabilities support a wide range of activities—from ultraprecise optics for the National Ignition Facility and metrology for extreme ultraviolet lithography to femtosecond laser cutters for stockpile stewardship and industrial applications.

3.3.2 Laboratory Directed Research and Development

Since its inception, Livermore's LDRD Program has provided support for many important and innovative scientific and technological advances. LDRD continues to play a vital role in developing new science and technology capabilities that respond to DOE and Laboratory missions and in attracting the most qualified scientists and engineers to the Laboratory. LDRD is one of the Laboratory director's most important tools for developing and extending Livermore's intellectual foundations, for enhancing its core strengths, and for driving its future scientific and technological vitality. It is an important vehicle for bringing new talent to Livermore through collaborative

research and postdoctoral opportunities. Research and development that expand the horizons of science and technology are essential to the continued vitality of the Laboratory and its ability to meet future mission needs.

LDRD was established by Congress as a means for DOE laboratories to directly fund creative, innovative basic and applied research activities in areas aligned with their principal missions but not immediately supported by sponsors. In FY 2001, LDRD funding was restored to the 6-percent level, that of years prior to FY 2000, with a budget of about \$55.2 million.

A Mission Focus. LDRD funds are reinvested in the mission areas of sponsoring programs and in R&D projects that align with the strategic vision of the Laboratory. Accordingly, Livermore's LDRD portfolio has a strong emphasis on national security. Each year, Livermore's proposed plan and requested program funding are evaluated against Congressional requirements regarding support of national security programs. Our assessments for the past four years and an estimate of the FY 2001 portfolio show national security sponsors of work at Livermore receive an LDRD return that far exceeds the investment—nearly 94 percent of the Laboratory's LDRD portfolio contributes to our national security missions.

In fact, all sponsors of research and development at the Laboratory draw a return greater than their LDRD investment. Livermore's LDRD portfolio reflects the Laboratory's focus on its special capabilities, which are applied to multiple mission areas, and on advancing those areas of science and technology to simultaneously address a number of enduring national needs. Many LDRD projects advance

capabilities that are important to more than one mission area—for example, ASCI-scale computing, fundamental materials science, advanced sensors and instrumentation, ultrashort-pulse lasers, and geoscience.

Program Thrusts

Livermore's LDRD Program has four project categories: Strategic Initiatives, Exploratory Research, Laboratory-Wide Competition, and Feasibility Studies. In FY 2001, about 27 percent of the funding was invested in Strategic Initiatives, about 66 percent in Exploratory Research, about 6 percent in the Laboratory-Wide Competition, and 1 percent in Feasibility Studies.

Strategic Initiatives. Strategic Initiatives are selected on the basis of their alignment with the Laboratory's strategic directions and long-term vision. Proposals for these projects are responsive to the R&D needs of at least one of the Laboratory's five strategic councils: the Council on National Security, the Council on Energy and Environmental Systems, the Council on Bioscience and Biotechnology, the Council on Strategic Science and Technology, and the Council on Strategic Operations. Strategic Initiatives are usually more challenging than projects in the other categories and typically entail the efforts of 5- to 10-person multidisciplinary research teams.

Exploratory Research. Exploratory Research proposals are submitted by the directorates, who first review the proposals to ensure their alignment with the directorate's strategic R&D requirements. The selection process for Exploratory Research projects weighs each proposal's ability to attract and develop young scientists, maintain the scientific and technological competence

of the Laboratory, further the organization's strategic vision, and reach academic and industrial communities.

Laboratory-Wide Competition. The Laboratory-Wide Competition provides all members of the Laboratory staff the opportunity to pursue their own creative ideas for one to three years. In this competition, the winning innovative projects further the missions of the Laboratory but are not required to pass a line-management filter.

Feasibility Studies. This special project category aims to increase LDRD's responsiveness to Livermore science and engineering with small projects to define and develop potential projects in the other three areas.

Although LDRD projects often address more than one scientific discipline, each project is classified into one of nine competency areas that are relevant to NNSA and Laboratory missions. The nine competency areas are:

- Advanced Sensors and Instrumentation.
- Atmospheric and Geosciences.
- Biotechnology and Health Care Technologies.
- Computing, Modeling, and Simulation.
- Energy and Environmental Sciences.
- Lasers, Electro-Optics, and Beams.
- Material Synthesis and Characterization.
- Nuclear and Atomic Science.
- Space Science and Technology.

Recent Accomplishments

Livermore's LDRD Program has been very productive since its inception in FY 1985, with an outstanding record of scientific and technical output. The program continues to provide many far-reaching scientific and technical accomplishments, which are described in detail in the Laboratory's LDRD annual reports (UCRL-LR-113717-01 for FY 2001).

National Security Support. The Laboratory's national security mission—stockpile stewardship of U.S. nuclear weapons and countering the proliferation of weapons of mass destruction—provides a focus for Livermore's LDRD portfolio. Representative highlights from the FY 2001 LDRD Program include:

- **Probing with the Falcon–Linac Thomson X-Ray Source.** This project, with collaborators at the University of California at Los Angeles, is developing and demonstrating a novel x-ray probe to understand the ultrafast dynamics of matter on the timescale of atomic motion—a picosecond or less. We expect the x-ray beam to make possible unprecedented dynamic measurements of high-atomic-number materials that are important in stockpile stewardship. In FY 2001, the project successfully completed major laser and linac modifications for optimal x-ray production, and in FY 2002, the project is conducting pulse-probe experiments.
- **Biological Assays Using Liquid-Based Detection Arrays.** The nation lacks a detection system that can quickly, accurately, and simultaneously detect the presence of many pathogens. This project is developing a prototype liquid array for conducting fast, inexpensive, portable, high-throughput, parallel pathogen detection. In this system, called the Microbead Immunoassay Dipstick System, the liquid array uses optical encoding of small-diameter beads serving as templates for biological capture assays. At the end of FY 2001, with excellent progress toward the goal for first responders to be able to run sophisticated diagnostics in the field, the project team was in the process of identifying potential partners who would commercialize the detector.

Awards and Recognition. Laboratory scientists and the research funded by

LDRD continue to garner national recognition. For example, PEREGRINE™, a three-dimensional Monte Carlo radiation dose calculation system, received a Federal Laboratory Consortium Award for Excellence in Technology Transfer in 2000. PEREGRINE™ was initiated through LDRD. In addition, CAPS, the Counterproliferation Analysis and Planning System, which began as an LDRD project and was later funded as a Work-for-Others project, was named by the Secretary of Defense as the preferred counterproliferation tool for use by the nation's armed services. CAPS is an extensive computer database and planning tool for analysis of worldwide weapons of mass destruction capabilities and response options. Furthermore, the team that discovered element 114, including LDRD-supported researchers from Livermore and scientists from Dubna, Russia, were honored for the discovery by both *Chemical Engineering News* and *Popular Science*.

Many patents and R&D 100 Awards from *R&D Magazine* have been earned for innovative technologies developed through LDRD-funded research. In FY 2001, 42 of the Laboratory's 89 patents were LDRD-based. Since 1978, 48 of 90 R&D 100 Awards given to Livermore scientists by *R&D Magazine* have been based on LDRD research, and in 2002, one of the five R&D 100 Award winners was based on LDRD research.

Student Support. The participation of scholars-in-training adds vitality to the Laboratory's R&D efforts and provides a pool of talented prospects for future career scientists and engineers. LDRD projects provide valuable support for student and postdoctoral research—103 students and 94 postdoctoral fellows in FY 2002.

Long-Term Benefits. Because of the nature of research, many years might pass before the full potential of a research and development project is realized. Several recently funded LDRD activities achieved major successes that have been broadly reported in the scientific communities as major scientific accomplishments:

- Research leading to extreme ultraviolet (EUV) lithography. LDRD-funded research in the 1980s provided much of the basic capabilities to enable the Laboratory to be a major player in a \$250-million cooperative research and development agreement (CRADA) with the leaders in semiconductor manufacturing.
- Biological weapon agent detection and identification. In a terrorist attack or on the battlefield, lives may depend on a quick determination of whether a biological agent has been used. LDRD-funded research led to the development of two highly portable and extremely sensitive technologies. Further developed under DOE/NSA sponsorship, the Handheld Advanced Nucleic Acid Analyzer (HANAA) has dramatically advanced biodetection capabilities and now provides real-time identification of bioagents in the field.
- Environmental cleanup technologies. For many years, LDRD has funded research projects to identify better methods for cleaning up soil and groundwater contamination. The program contributed to the development of two technologies, dynamic underground stripping and hydrous pyrolysis/oxidation, that have been successfully demonstrated in Visalia, California. These technologies are now being used for site cleanup at two major DOE facilities, the Portsmouth Gaseous Diffusion Plant in Ohio and the Savannah River Site in South Carolina.

3.4 Partnerships and Collaborations

Many Livermore research and development activities are executed in partnership with industry, academic institutions, and other laboratories. Partnerships and collaborations are often the most cost-effective way to accomplish our programmatic goals. In addition, Livermore has a responsibility to move appropriate technologies developed in the course of our mission work into the marketplace, where the advances can have the maximum positive effect on the U.S. economy or other important national priorities.

Program Thrusts

Partnerships That Create New Capabilities. Partnering has been important at the Laboratory ever since our establishment as part of the University of California and the early days of supercomputer development to meet the needs of the weapons program. Partnering will play an even more significant role in the future. Activities will continue to span a wide range—from very large-scale strategic alliances and “virtual laboratories” to licensing of individual technologies, academic research, and support for the small business community. For example, the Laboratory is one of the founding partners (with Sandia, the city of Livermore, and private-sector sponsors) of the Tri-Valley Technology Enterprise Center (TTEC), a regional business incubator under the aegis of the Tri-Valley Business Council. TTEC is providing support for start-up high-technology companies. We also work with others to share expertise and make available research capabilities.

Effective Academic Collaborations and Science Education Programs. As a part of the University of California and as a

national laboratory, Livermore shoulders significant science education responsibilities. By making the Laboratory's research facilities and staff accessible to the academic and industrial communities, we provide valuable opportunities to visiting researchers while we strengthen our science and technology base. Academic collaborations bring new science and technology to the Laboratory's national security programs and help attract and retain outstanding technical staff. We are home to several University of California scientific research institutes and other unique facilities that support hundreds of ongoing projects with faculty, postdoctoral fellows, and graduate students. We also help train the nation's next generation of scientists and engineers through our science and technology outreach programs that span all educational levels.

3.4.1 Partnerships with Industry

Situation and Issues

Livermore is committed to partnering with U.S. businesses and industries. We anticipate that the Laboratory's partnerships and alliances with industry will continue to grow. We work with U.S. companies for various reasons and use a variety of partnering mechanisms. Most importantly, we form partnerships with industry to support our national security mission. For example, our participation in a consortium to develop advanced technologies to manufacture computer chips will also enhance critical advanced computation capabilities at the Laboratory. Technology transfer also promotes economic development and national competitiveness. Finally, the areas of environmental remediation and health care provide examples where we "spin off" for public benefit Laboratory-developed technologies through

mechanisms such as CRADAs and technology licenses.

Livermore's interactions with U.S. industry are exemplified by our 103 active licensing agreements, 35 active CRADAs, 100 industrial Work-for-Others agreements, 136 reported inventions, 129 patent applications, 38 foreign patent applications, and 104 issued patents in FY 2002 (Table 3-1).

The Laboratory has loaned space to the Tri-Valley Technology Enterprise Center to establish an onsite resource center for small businesses and start-up companies from the local area, including any that originate from Lawrence Livermore or Sandia/California or that partner with them. TTEC was established through a collaborative effort of the city of Livermore, the Tri-Valley Business

Council, Sandia and Livermore national laboratories, and local businesses. It is aimed at promoting the economic vitality of the local region and helping facilitate a bridge between the laboratories and the local technology community.

Livermore's Industrial Partnering and Commercialization Office (IPAC) facilitates many interactions with industry. IPAC provides information on licensing, cooperative research, and other opportunities for businesses to benefit from technology transfer, and it negotiates the contracts that govern the relationships.

Partnering Mechanisms and Activities

Licensing Agreements. Through licenses, Livermore grants permission

Table 3-1. Laboratory interactions with industry, FY 1998–2002.

Type of interaction	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	Totals
Licenses of Laboratory patents and copyrights						
Number issued	49	35	33	36	40	193
Royalties (\$M)	2.6	2.2	3.6	3.4	3.2	15
DOE (TTP) CRADAs						
Number active	33	7	0	1	1	–
DOE funding (\$M)	2.1	1.0	0	0	0	3.1
Lab-funded CRADAs						
Number active	22	25	18	10	10	–
Lab/DOE funding (\$M)	2.2	2.2	2.3	1.7	1.0	9.4
Industry-funded CRADAs						
Number active	28	34	29	28	29	–
Industry funds-in (\$M)	29.1	31.3	21.0	19.2	13.7	114.3
Work-for-Others projects with industry						
Number active	90	113	99	165	101	–
Industry funds-in (\$M)	9.1	8.1	14.5	9.6	4.4	45.7
Procurements for research & development						
Number active	548	267	207	263	251	–
Amount (\$M)	191.8	98.1	97.4	82.4	55.6	525.3
Start-up companies (number)	3	1	3	3	6	16

Note: Data from LLNL interaction with industry have been updated to reflect current reporting practices.

for commercial and noncommercial access to reproduction, manufacture, sale, or other exploitation and use of Laboratory-developed intellectual property. As an example, exceptionally effective environmental cleanup results were achieved using the Laboratory's dynamic underground stripping technology to clean up groundwater contamination at a Southern California Edison site previously used to treat power poles with preservatives such as creosote. Dynamic underground stripping and important auxiliary technologies were licensed to SteamTech Environmental Services to perform the cleanup operations. The award-winning technology has subsequently been licensed to Integrated Water Resources Inc. of Santa Barbara, California, and Southern California Edison. At DOE's Savannah River Site, 20,000 pounds of solvents were removed—20 times more than estimated—from a small area.

Our licensing efforts include the following recent highlights:

- Livermore signed a license in 2002 with Field Forensics Inc. for two field-portable solid-phase micro-extraction (SPME) kits and a SPME fiber reconditioning unit. Field Forensics Inc. is a small business located in Tierra Verde, Florida, dedicated to the support of law enforcement, antiterrorism, treaty enforcement, and disaster response with technologies that afford efficient and safe forensic sampling. The purpose of this license is to develop, manufacture, and distribute SPME field-sampling analysis kits and peripheral equipment that allow the reuse of the expensive and ultrasensitive SPME fibers. The company also intends to support agencies involved in chemical warfare agent counterproliferation and antiterrorist activities.

- Also in 2002, Livermore signed a license with a small New Jersey corporation to enable it to supply gratings mainly to universities, companies, and U.S. government research and development laboratories. The company, a leading manufacturer and innovator of diffraction gratings, will use the license for multilayer dielectric diffraction gratings useful for developing multiwavelength laser systems such as those used in telecommunications systems with short-pulse and pulse-compressed lasers.

- In 2001, Cooper Electronic Technologies, a Fortune 500 company, acquired Livermore-licensee PowerStor® to supply a growing supercapacitor market uniquely positioned between a \$15-billion battery market and a \$9-billion capacitor market. In 1997, PowerStor® was spun off from PolyStor to concentrate on developing advanced capacitors, called supercapacitors or ultracapacitors, using Livermore's carbon aerogel technology for pulsed-power and electronic circuitry applications in multibillion-dollar battery and capacitor markets. Aerogel supercapacitors are capable of storing hundreds of times more charge than conventional capacitors.

- In 2001, pharmaceutical industry leader Abbott Laboratories acquired Vysis, an Illinois genomic disease management company that has licensed Livermore's chromosome painting technology. Chromosome painting enables the evaluation and management of certain genetic diseases, potentially allowing treatments customized to each patient's needs. The technology produces a new powerful breed of diagnostics to aid physicians in determining who is at risk for disease, identify molecular changes that indicate diseases such as cancer before symptoms

appear, and determine individual treatments. Six Vysis products have been either cleared or approved by the Food and Drug Administration, including a breast cancer diagnostic kit for treating a disease afflicting 1.7 million Americans. The Laboratory's chromosome painting technology won an R&D 100 Award in 1994.

Partnerships through CRADAs and Work-for-Others. We also work with U.S. industry through a variety of CRADAs in which intellectual property rights are negotiated. Many CRADAs were initiated in the mid-1990s with substantial funding provided by a DOE program designed to support technology transfer. Livermore's CRADAs are increasingly either Laboratory-funded (cooperative efforts on technologies we vitally need) or funds-in projects (industry backing for cooperative efforts). In addition, we engage in industrial Work-for-Others (WFO). These agreements provide non-DOE organizations with access to highly specialized or unique DOE facilities, services, or technical expertise.

One major funds-in CRADA is a project to develop technologies to produce smaller, more powerful computer chips. Researchers from the Livermore, Sandia, and Berkeley national laboratories have formed a Virtual National Laboratory that is working with an industrial consortium including Intel, AMD, Motorola, Micron, IBM, and Infineon as major partners. Our work focuses on the use of extreme ultraviolet lithography (EUVL) as a means for etching ultrathin patterns into silicon chips. EUVL technology relies on Livermore expertise in multilayer coating technology and ultraprecision optics metrology.

A much smaller CRADA was signed with Spectra Gases Inc. in April 2002.

The Alpha, New Jersey, company manufactures specialty gases for high-technology markets, such as medical and research laser systems. The purpose of the CRADA is to develop new and cheaper sources of oxygen-18, carbon-13, and xenon-129 and to develop new medical applications of these stable isotopes. A Former Soviet Union (FSU) institute is another party to the CRADA, which is funded in part by NNSA, as part of the U.S. Industrial Coalition Program, supporting civilian R&D projects to employ FSU weapons designers.

In 1999, the Laboratory announced the selection of NOMOS Corporation of Sewickley, Pennsylvania, to commercialize PEREGRINE™, an improved dose-calculation system for extremely precise planning and application of cancer radiation treatment. In addition to issuing a license, we are assisting NOMOS in commercialization efforts under a WFO agreement.

We currently have active CRADAs and WFOs in fields as diverse as medical devices, advanced manufacturing, and microtechnologies. Our small-business activities also include CRADAs and participation in the Small Business Innovative Research (SBIR) program.

Partnerships through Procurement.

Livermore has always pursued industrial partnering through its procurement strategy. To cost effectively acquire the state-of-the-art technologies needed for our major research and development programs, we continually interact with private industries to understand their capabilities and products so that we can make informed decisions.

For example, over 75 percent of the total funding for construction of the National Ignition Facility will go to U.S. companies, including high-technology firms producing optical components. In

some cases, Livermore's programmatic needs actually spur the development of new businesses or new product lines in existing companies. Advances in the state of the art may be developed here and transferred to a commercializing partner or developed by the company to meet our requirements in order to generate a production-scale source of equipment, instrumentation, or components for some of our larger experimental facilities.

Similarly, in the ASCI Program, DOE Stockpile Stewardship computational requirements are driving computer advancements and refinements of prototype machines. The laboratories are acquiring increasingly powerful supercomputers from U.S. industry and, in turn, helping these companies ready their new products for the wider marketplace. Table 3-1 shows our interactions with industry for FY 1998 through 2002.

Honors and Awards. The Laboratory continues to be recognized for technology transfer activities. We won six R&D 100 Awards in 2002, and since 1978, LLNL researchers have garnered 91 R&D 100 Awards. The Laboratory's six plaques in 2002 represented the highest total for any Department of Energy research laboratory and of any organization participating in that year's competition, according to officials with *R&D Magazine*. The awards are given annually by *R&D Magazine* for the top 100 technological achievements that promise to improve people's lives through breakthrough products and processes. Winning entries are selected on criteria that include proof of product. The winners for 2002 are:

- The Solid-State Heat-Capacity Laser. With an output of 13,000 watts, this laser represents the most powerful solid-state laser system in the world. The

technology for this compact high-average-power laser offers a range of applications for military defense and industrial processing.

- Silicon Monolithic Microchannel Cooled Laser Diode Array. This modular packaging technology allows the production of the smallest and most powerful laser diode pumps ever.

- STIM-2002. This instrument is a miniaturized and condition-specific medical device that delivers low-level electrical pulses through the skin to inhibit or interfere with pain signals to the brain. This award is also shared with two companies, Cyclotec Advanced Medical Technologies Inc. and Biophysical Laboratory Ltd.

- Production-Scale Thin Film Coating Tool for Next-Generation Semiconductor Technology. This machine enables the successful implementation of the EUVL project as the technology for manufacturing the next generation of microprocessors, leading to computers that will be 100 times faster than those currently available. The award is shared with Veeco Instruments Inc. of New York.

- In Situ Rolling Circle Amplification (IRCA). This new technique extends the use of RCA to tissue biopsy by precisely locating in a single cell a damaged or abnormal gene that indicates the presence or tendency toward a particular disease.

- Hierarchical Data Format 5 (HDF5). The National Center for Supercomputing Applications (NCSA) received the award for HDF5, a file format and a software library for storing, managing, exchanging, and archiving large, complex scientific, engineering, and other data. The technology came from a close collaboration with LLNL's Computations Directorate and B Division, as well as with workers at Sandia and Los Alamos.

In addition, Livermore licensee Cepheid, a California company founded in 1996, won an R&D 100 Award this year for its Livermore-developed GeneXpert fully automated gene analysis system. Technology licensed from the Laboratory is at the heart of the instrument. Cepheid recently received attention for its field-ready DNA testing systems for rapid detection of deadly biothreat agents such as anthrax. For obtaining biological analyses in the field, Cepheid's portable Smart Cycler, also based on Livermore technology, won an R&D 100 Award in 1998.

3.4.2 Teamwork with Other Laboratories

We are working with other national laboratories to coordinate and integrate

programmatic efforts to provide the best scientific and technical capabilities for the dollars invested. Livermore's collaborative activities are increasing through participation in integrated national programs, such as the Stockpile Stewardship Program and the Joint Genome Institute. Collaborations include the design, construction, and shared use of major research facilities such as Livermore's National Ignition Facility and many other projects described throughout Sections 2 and 3.

Factors critical to the success of these team efforts include effective high-level DOE leadership, well-defined program goals and deliverables, complementary capabilities among the national laboratories, confidence in each other's commitment and performance, and a healthy competition of ideas within a collaborative framework.

3.4.3 University Collaborative Research

Individual collaborations between Livermore scientists and university faculty and students have taken place since the Laboratory was founded. Our research collaborations with university faculty and students are designed to blend basic research with applied researchers. The collaborations provide effective ways for unique Laboratory facilities and expertise to be made available to the broad U.S. research community. Table 3-2 shows Livermore's collaborations with universities from FY 1999 through FY 2001.

University Relations Program. The Laboratory's University Relations Program encourages and expands research collaborations between Livermore and universities and other research organizations. The program contributes to the intellectual vitality of all the partners through basic and applied research collaborations. By facilitating the flow of ideas and people between institutions and by making our unique facilities and expertise available to students and faculty, we address problems that are of interest to the broad U.S. research community and important to the nation.

The University Relations Program also oversees the Laboratory's science and technology education efforts (see Section 3.4.4). We help train the nation's next generation of scientists and engineers through our outreach programs that span all educational levels. The Laboratory also benefits by enlarging the pool of talent and raising awareness about Livermore and its national security mission—our continuing success depends on recruiting and retaining quality staff.

Table 3-2. Laboratory–university collaborations FY 1999–2001.^a

Type of collaboration	FY 1999	FY 2000 ^b	FY 2001
Collaborations with the University of California			
Total number	533	460	542
UC faculty	221	177	247
UC students	312	283	295
Collaborations with other California universities			
Total number	176	109	155
Faculty	84	40	51
Students	92	69	104
Collaborations with non-California universities			
Total number	625	513	580
Faculty	358	253	322
Students	267	260	258

^aUniversity and college faculty and students involved in collaborative work programs with the Laboratory at Livermore, at their home institutions, or both.

^bThe number of collaborations dropped in FY 2000 and 2001 due in part to lower funding levels.

Livermore—University of California Research Institutes

Several Livermore–university institutes have been established in specific subject areas, setting a focus for collaborations with the nine University of California campuses as well as with many other universities. The institutes provide a hospitable environment for visiting students and faculty. They advance Livermore’s strategic goals by aligning subject matter with expertise needed to execute Laboratory programs. The institutes include:

Institute of Geophysics and Planetary Physics (IGPP).

The Livermore branch of IGPP (a Multi-Campus Research Unit) runs the Astrophysics Research Center, which carries out a significant research program and manages the astrophysics part of the University Collaborative Research Program (UCRP). The Center for Geosciences in IGPP promotes UC collaborative research in the earth sciences. The center’s research emphasis is on the physics and chemistry of Earth, including seismology, geochemistry, experimental petrology, mineral physics, and hydrology.

Center for Accelerator Mass Spectrometry (CAMS).

Processing more than 20,000 samples per year with its extremely sensitive measurement capability, CAMS supports research programs that range from archaeological dating to biomedical research, and from global climate change to geology. The capabilities of CAMS are available to all qualified users under standard DOE procedures. Some 75 service contracts are currently in place with nonprofit foundations, non-DOE agencies, and private corporations.

Institute for Scientific Computing Research (ISCR). ISCR fosters collaborations between Laboratory and

academic researchers in the areas of scientific computing, computer science, and computational mathematics. These topics are central to large-scale scientific simulations for the Stockpile Stewardship Program, and in particular for ASCI. The institute is the administrative host to dozens of graduate students, postdoctoral fellows, and visiting faculty, and it fosters substantial collaborations that take place on UC campuses. As of FY 2000, ISCR also administers the university portion of the ASCI Institute for Terascale Simulation at Livermore.

Institute for Laser Science and Applications (ILSA).

ILSA is a center of excellence at Livermore in the areas of laser science and novel applications of high-power lasers. The institute focuses on high-peak-power lasers, ultrahigh-speed diagnostics, and the interaction of high-energy particles with plasmas. The institute coordinates the usage of the Livermore Research Laser Facilities (LRLF) and facilitates the participation of outside collaborators. University of California campuses—principally Davis, Berkeley, and Los Angeles—are active collaborators and participants in ILSA-supported projects. Collaborations with other universities across the country are extensive and continue to expand. ILSA also has an important educational mission to train next-generation researchers in laser science and high-energy-density physics.

Materials Research Institute (MRI).

MRI fosters collaborations between Livermore and both academic and industrial researchers. The goal is to help provide the Laboratory with basic science opportunities that could have potential relevance to our missions. Our main focus is currently on two areas: materials under extreme conditions, and nanoscience and nanotechnology.

Recently, MRI has developed a graduate fellowship program in energetic materials and a summer institute for computational materials science and chemistry.

Physical Biosciences Institute (PBI).

The new Physical Biosciences Institute is an incubator for multidisciplinary projects linking novel Livermore experimental and simulation capabilities to high-impact biosciences research challenges to achieve a quantitative and predictive understanding of dynamical cellular processes. The PBI research staff will consist of postdoctoral fellows and graduate students from many disciplines. PBI projects under development involve collaborations with researchers in nearly all directorates as well as with faculty at several UC campuses, including the Natural Sciences Division at the new UC Merced campus.

Other University Interactions

Department of Applied Science (DAS).

A part of the College of Engineering at the University of California at Davis, DAS has facilities at both Davis and Livermore. It offers a limited number of temporary positions to selected UC Davis graduate students who then work in one of the Laboratory’s major research facilities while conducting thesis research related to the programmatic research. In 1998, after a comprehensive review of the UC Davis DAS program, the Livermore student fellowship program was broadened beyond applied science and computer science to include all relevant UC Davis departments.

University of California Directed Research and Development (UCDRD).

Other collaborative activities among the three UC-managed DOE national laboratories are supported by two funds established by the UC–DOE

management contract. The UCDRD fund is available to support research activities at the discretion of each laboratory director. Livermore uses UCDRD funds for strategic investments at the Laboratory and for integrating support with other UC collaborative efforts. The Complementary and Beneficial Activities (CBA) Fund was established specifically to support collaborative research efforts through the Campus–Laboratory Collaborations (CLC) Program and the Campus–Laboratory Exchange (CLE) Program.

The CLC is a multidisciplinary, multilocation research program that funds three-year projects to address complex issues having significant social and economic impact on California. Eligible participants are scientists from all UC campuses working in partnership with researchers from Los Alamos or Lawrence Livermore national laboratories. Similarly, the goal of the CLE Program is to enhance and facilitate collaboration among the nine UC campuses and the laboratories. The program supports the exchange of people between the campuses and the laboratories.

Lawrence Livermore Fellowships.

Among the research opportunities offered by the Laboratory is the Lawrence Livermore Fellowship, a distinguished postdoctoral program established in 1998. The fellows have world-class resources to support their research. Fellowships are awarded only to candidates with exceptional talent, credentials, scientific track records, and potential for significant achievements. The fellows are expected to do original, independent research in one or more aspects of science relevant to the competencies of the Laboratory.

Sabbatical Program. The Lawrence Livermore Sabbatical Program was

initiated in FY 2001 to encourage faculty in leading universities worldwide to spend their sabbaticals at the Laboratory. The program has three major objectives: to provide faculty access to new scientific or engineering expertise in Laboratory programs, to familiarize Livermore's new visiting faculty with our mission and capabilities, and to enhance existing relationships so that these faculty members return to their campuses as ambassadors who will assist in the recruitment of future Livermore employees among their students. Selected faculty are strongly encouraged to include postdoctoral or graduate students in their sabbatical programs. Eight faculty and 16 students participated in the program's first year.

The Research Collaborations Program (RCP). Livermore's Research Collaborations Program for Historically

Black Colleges and Universities (HBCUs) and other minority institutions is a Laboratory-wide program. RCP develops and promotes productive and mutually beneficial scientific collaborations between accomplished faculty and students from these institutions and Laboratory principal investigators in areas of core competency. The program provides unique research opportunities for participants and provides the Laboratory additional expertise and staffing for basic research efforts.

University of California at Merced

The University of California is developing plans to open a tenth campus in Merced, California, in 2004. The new campus, which will eventually serve 25,000 students, plans to have a close affiliation with Lawrence Livermore.

Table 3-3. FY 2001 STEP NNSA-sponsored college student internship projects and participation.

Partners and STEP internships in national security projects	Number of interns
NNSA/DP–Laboratory Critical Skills Development Program	110
Accelerated Strategic Computing Initiative (ASCI) Pipeline	
College Cyber Defenders (CCD)	
Interns for Defense Technologies (IDT)	
Internships in Terascale Simulation Technology (ITST)	
Inertial Confinement Fusion Experimental Internships (ICFEI)	
Laser Science and Technology Student Program (LSTSP)	
National Ignition Facility Laser Internships (NIFLI)	
Nuclear Science Internship Program (NSIP)	
System Administration Computer Support	
Livermore NNSA Directorates	25
Computational Materials Science and Chemistry Institute	
High-Energy-Density (HED) Physics Program	
Livermore National Security Office	35
Military Academic Research Associates (MARA)	
Reserve Officer Training Corp (ROTC)	
Total partners and internships	170

UC Merced will be the first American research university built in the 21st century. In October 2000, a Memorandum of Agreement was signed by principals from UC Merced, Merced Community College, and the Laboratory to create academic partnerships among the three institutions.

UC Merced planners meet regularly with senior Livermore managers on a wide range of issues. We are helping to establish this new campus by: contributing to the definition of scientific and engineering programs at the campus, consulting on the physical plant (e.g., energy efficiency, waste management), helping plan the programs for UC Merced's Sierra Nevada Research Institute, and serving on search committees for senior staff. Once the new campus is operating, UC Merced and the Laboratory expect to collaborate on research projects, student internship programs, and joint appointments that will provide opportunities for Livermore personnel to teach. Over time, we expect UC Merced to become an important source of future employees for the Laboratory.

3.4.4 Science and Technology Education Program

The Laboratory's Science and Technology Education Program (STEP) serves as a resource to students, teachers, and faculty by facilitating research interactions with Livermore's world-class scientific facilities and staff (Tables 3-3 and 3-4). STEP also supports the science educational needs of the local and regional communities surrounding the Laboratory. STEP leads our science education activities, which are directed toward:

- Facilitating research internships for college students entering careers

important to the intellectual capability required by Livermore's national security mission.

- Enhancing science literacy and science education through technical partnerships with the K–14 education community.

The common theme of our science education effort is the integration of education, research, and career options at all school levels—pre-college, undergraduate, and graduate school—

through Livermore-sponsored projects. STEP's "school-to-career" education projects make an important long-term contribution to national security. The program further benefits the nation by helping the U.S. to compete successfully in the world marketplace and remain a major economic power. (For more information about activities and annual reports, see the STEP Website at <http://step.llnl.gov/>.)

Table 3-4. FY 2001 STEP science outreach and science education projects.

Science outreach (K–12 students)	Participants
COSMOS (UC program) Crystals in the Classroom Expanding Your Horizons (3 conferences) Explorer Post Fun with Science (teachers, parents, and students) Future Scientists and Engineers of America Groundwater Assessment Course Math Challenge Optics and Lasers Course Planning Your Future Conference Science on Saturdays Student Research Academy Tri-Valley Science and Engineering Fair	
Total science outreach participants	13,200
Science education (K–14 teachers)	
Computer Technology Workshops Crystals in the Classroom Edward Teller Science Education Symposium Faculty Research Experiences (Merced College) HOT Topics in Science/GEMS Laser Science and Optics in the Classroom Planning Your Future Conference Promoting Achievement through Hands-On Science Teacher Research Academy UC/Community College/Central Valley Education Web Tech Academy	
Total science education participants	1,200

College Student Research Internships

STEP facilitates partnerships and collaborations with the education community to help ensure a highly skilled, diverse workforce for the science and technology challenges of the Laboratory's national security mission. During FY 2002, 170 college, university, and academy students participated at the Laboratory in internships administered by STEP (Table 3-3).

The majority of stockpile stewardship internships is funded directly by NNSA Defense Programs' Laboratory Critical Skills Development Program. Individual interns are recruited to support the specific needs of Laboratory programs, such as terascale simulation supporting ASCI. STEP's internship projects target undergraduate and graduate college students in four major disciplines: currently targeted "critical skills" in chemistry and materials science, computer science, engineering, and physics. For example, STEP partners with various Livermore program elements in stockpile stewardship, such as high-energy-density physics, to develop recruiting programs aimed at specific college students. STEP also works with our National Security Office to provide internship opportunities for U.S. military academy cadets, midshipmen, and college ROTC students to contribute to common mission goals between DoD and DOE. (For more information, see the STEP Website at http://step.llnl.gov/step_student.html).

Science Outreach and K–14 Educator Partnerships

Through local and regional education partnerships, STEP leads the Laboratory's education efforts to stimulate greater interest in science and technology among teachers and school administrators and to encourage students to pursue scientific and technical careers after high school. The science outreach and educator projects are funded by the Laboratory's General and Administrative (G&A) Distributed Budget.

Pre-college science literacy activities play an important role in the creation of future scientists, engineers, and technicians by enlightening students about potential careers in science and technology, especially those of special interest to the Laboratory. STEP's K–14 partnerships with the education community are aligned with the new science standards of the State of California.

By providing a continuous school-to-career roadmap for pre-college, undergraduate, and graduate students interested in science and technology, STEP will continue to offer intriguing opportunities to further students' careers in science research through hands-on internships, projects, and partnerships.

STEP's science outreach and educator projects during FY 2002 engaged approximately 1,000 teachers and 13,000 students (Table 3-4). Many of the K–14 projects are described on the STEP Website (<http://step.llnl.gov/>) on its educator resources and education outreach links.

3.5 Work-for-Others

The Laboratory pursues research and development for federal sponsors other than DOE, state agencies (particularly California), and in some cases, for private industry through funds-in-CRADAs. These activities are mutually beneficial to the work sponsor and the Laboratory, as depicted by the diagram that illustrates our mission statement (see Figure 1-1). Livermore's special capabilities (skills and facilities) meet the requirements of the work sponsors. The projects are supportive of the principal mission thrusts of the Laboratory and enhance the capabilities needed to perform these missions. Because a principal feature of the Work-for-Others projects is that they are synergistic with major missions at Livermore, each Work-for-Others project is managed by the directorate at the Laboratory that is the source of expertise and technically responsible for the work.

Department of Defense. The Laboratory participates in approximately 250 individual projects in support of DoD programs. Some of these efforts support particular DoD needs and requirements that can best be achieved using Livermore's capabilities and expertise. Many constitute technology development and application efforts for which the results are of direct interest and benefit to both DoD- and NNSA-sponsored programs at the Laboratory. The total Laboratory budget for DoD and defense-related work was over \$75 million in FY 2001. Section 2.2

highlights our work to stem the proliferation of weapons of mass destruction, and Section 2.3.1 discusses our other principal areas of focus.

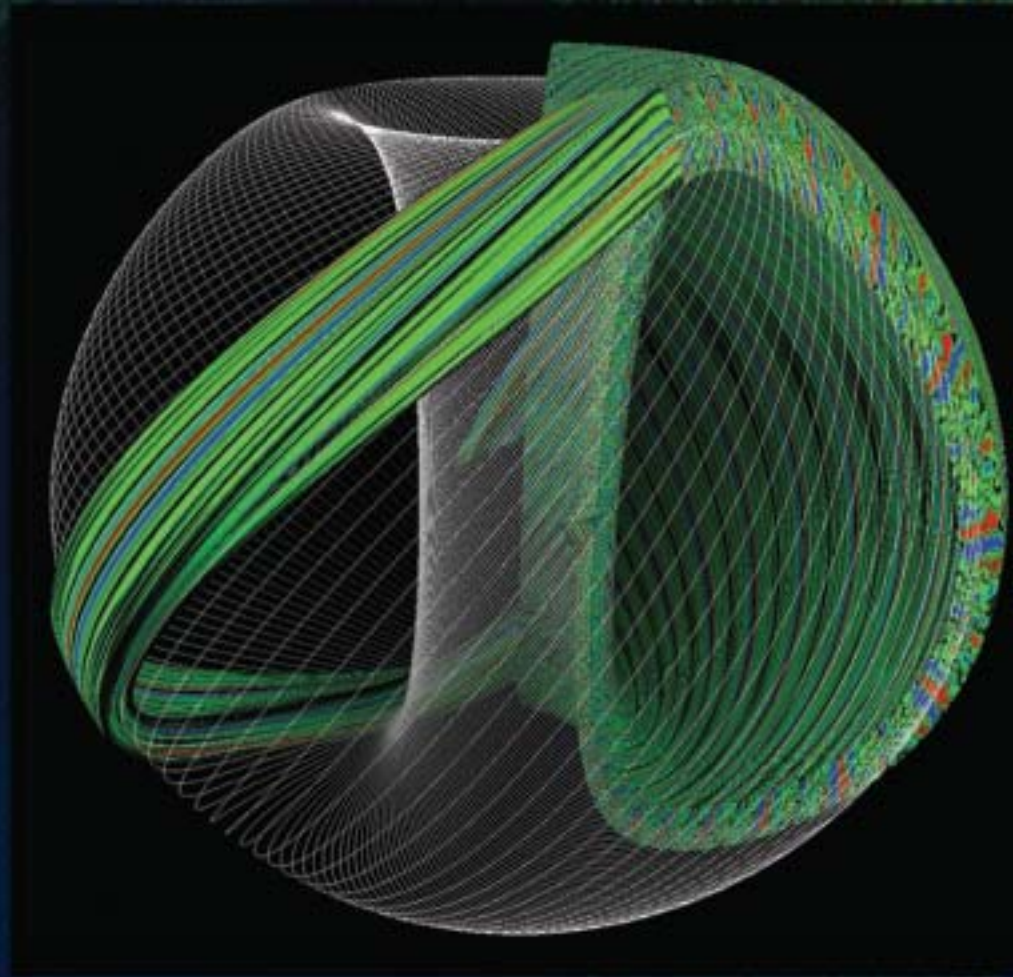
Other Federal Agencies. The Laboratory's work for other federal agencies largely entails projects for NASA, NIH, and various intelligence organizations. The diverse portfolio of activities for NASA, which builds on special competencies at Livermore, comprises four general areas: advanced detector development, theory and computational models for analysis of spectral data from satellite missions, laboratory experiments to test theoretical spectral models, and observations and analysis (see Section 3.3.1). Similarly, our work for NIH includes a variety of projects that take advantage of Livermore's special capabilities (see Section 3.2). For example, CAMS is being made available to biomedical researchers who need this accurate tool to measure very low levels of carbon-14. NIH is providing funding to make CAMS a designated National Resource for Biomedical Accelerator Mass Spectrometry.

Non-Federal Work-for-Others. The Laboratory conducts nearly \$40 million of research for industry, state agencies, foundations, and local governments. With a few exceptions, these projects are typically small and of short duration. Our work with industry, which includes CRADAs and licensing agreements, is discussed in Section 3.4.1.

SECTION 4

Institutional Plan FY 2003–2008

Laboratory Operations



Simulations of the extraordinarily complex physics involved in magnetically confined plasmas using the PG3EQ code complement Livermore's experimental efforts in magnetic fusion. This simulation shows a white magnetic field line wrapping around a torus, or doughnut-shaped configuration of plasma. Colors indicate microturbulent fluctuations in the plasma density.

IN all Laboratory operations, we strive to set a standard of excellence in environment, safety, and health; security; and business practices among high-technology applied research and development institutions. These factors are the underpinnings of success for all Livermore programs.

The importance of quality operations and administration to the success of the institution is reflected in significant high-level organizational changes that were made in 2001. Three new directorates were created—Safety, Security, and Environmental Protection; Administration; and Laboratory Services—and associate directors were appointed to lead the new organizations. The changes ensure high-level attention to important Laboratory operational issues while lessening line-management responsibilities in the Director’s Office. The Deputy Director for Operations has greater opportunity to focus on broader, more strategic issues for the Laboratory and work institutional issues with the management teams at the National Nuclear Security Administration (NNSA) and the University of California.

The Laboratory’s operations serve many customers—the technical programs, sponsors, Congress, Laboratory employees, and the local community to name just a few. To best meet the diverse needs of these stakeholders and customers, the Laboratory takes an integrated approach to operations and balances attention to technical capabilities, services, and infrastructure in a way that best supports our overall objectives. Five overarching strategies reflect Laboratory priorities for operations.

Safety is a Top Priority

Livermore has implemented DOE’s Integrated Safety Management System (ISMS) throughout our workforce, both

onsite and offsite. With DOE’s seven guiding principles and five core functions as the foundation, ISMS establishes the basis for work authorization at the Laboratory. The introduction of ISMS at the Laboratory has affected a cultural change through which operations are carried out safely and efficiently under an umbrella of Work Smart Standards. Livermore’s ISMS implementation has been validated by DOE, and the DOE Office of Independent Oversight and Performance Assurance concluded in its assessment that “OAK [DOE/Oakland] and LLNL have worked cooperatively to establish and implement a comprehensive ISM program.”

ISMS is integrated into all levels of work, including procured services. Operational support organizations receive training to assist the responsible individuals who are performing the work, and they in turn are trained to implement the ISMS principles.

A Commitment to Strengthened Security

The events of September 11, 2001, reinforced the prime importance of security at the nuclear weapons laboratories. Since 1999, Livermore, Los Alamos, and Sandia national laboratories have been working closely with the Secretary and other DOE and NNSA managers to tighten security and establish a baseline for an even more integrated approach to security.

We have increased our investments in security to ensure compliance and to adjust to new security threats and challenges arising from rapid changes in information technologies. In particular, we are providing even greater protection of critical assets at Livermore and implementing state-of-the-art computer security, and we expanded our counterintelligence program. However,

additional investments are needed for preparedness in response to the terrorist attacks. To that end, we are taking steps to further increase physical and computer security and security awareness at the Laboratory.

In January 2000, the NNSA laboratories and the University of California Office of the President began work on developing an approach for implementing Integrated Safeguards and Security Management (ISSM). In January 2002, UC approved the Laboratory’s ISSM project plan to integrate safeguards and security into management and work practices at all levels so missions are accomplished securely.

An Emphasis on Teamwork

Since the founding of the Laboratory by E. O. Lawrence in 1952, team science—the ability to respond to challenges by forming multidisciplinary teams to get the job done—has been one of Livermore’s key strengths. Teamwork is a broadly applied principle at the Laboratory—using a matrix management system to focus scientific and engineering talent where needed and integrating operational support with programs to achieve mission success. To seamlessly integrate Laboratory operational support with programs, staff and systems must be flexible, agile, and cost effective, adding value to Livermore’s technical work. Many critical aspects of smooth and effective Laboratory operations, such as safety, security, and environmental protection, are every employee’s responsibility.

Strategic Institutional Investments

Livermore’s achievements are the product of dedicated, high-quality efforts by all employees. As a consequence, attention to workforce recruitment, training, and retention is critically important. Investments in people are

investments in Livermore's future. The Laboratory supports training, education, and career development programs for individuals that meet their needs for growth and are consistent with Laboratory goals. We must ensure that employees have the best skills, training, and tools to accomplish their current work and to prepare for future assignments.

In addition, the Laboratory has been reinvesting to meet specific objectives directed at strengthening the Laboratory's scientific and technical base, meeting critical infrastructure and facility needs, and realizing long-term cost savings through one-time investments anticipated to have high return-on-investment ratios. Specific areas pertaining to Laboratory operations, such as facilities maintenance, have been identified as high-priority items for institutional reinvestment.

The reinvestments have been made possible through the implementation of a well-defined initiative to streamline business practices, improve information management, and outsource services when practical and cost effective. The result has been about a 30-percent reduction (inflation adjusted) in traditional General and Administrative (G&A) costs since FY 1993. We continue to look for ways to obtain further cost reductions to benefit Laboratory programs and enable the institution to meet strategic reinvestment needs.

Our commitment to improving operations includes ongoing efforts to substantially reduce the "administrative workload burden" at Livermore—in conjunction with both the NNSA-wide effort to reengineer operations and the need to improve processes that we control internally to the Laboratory. We

are actively involved with the several NNSA Task Groups working issues, and we have identified focus areas for our internal efforts through solicited input from program and project leaders as well as working scientists and engineers. Focus areas include streamlining processes for ISM, hiring, internal decision making, document review and release, Laboratory Directed Research and Development, Work-for-Others programs, and facility and project management. In addition, we are working to better balance and leverage information technology (IT) investments across the Laboratory. The Laboratory's new chief information officer, hired in June 2002, is working to formulate a vision and goals to maximize IT solutions.

Use of Performance-Based Management to Improve Operations

In 1992, the University of California (UC) and DOE pioneered a contracting approach that integrated performance-based requirements into the contract for managing and operating the three UC laboratories. Performance-based management is contributing to improvements in Laboratory operations in several significant ways:

- Benchmarks to understand norms and improve performance measures. Across almost the entire spectrum of operational activities, we are benchmarking our performance with that of other research and development laboratories to find ways to better gauge performance and identify specific areas that warrant improvement.
- Use of performance measures to improve operations. Through iteration and continual improvement of the self- and DOE-assessment processes, Livermore has markedly improved

operations, as measured by factors such as cost efficiency, service timeliness, and work quality.

- Performance-based management as a means of building teamwork. In addition to team building within the Laboratory, Livermore's performance-based management system is fostering a closer working relationship among the Laboratory, UC, and DOE. Through a variety of forums, we are achieving better communication of performance expectations, more efficient oversight, and ultimately, improved performance.

The UC laboratories, the University, and NNSA are looking to improve the performance-based management process. Significant efforts by Livermore, Los Alamos, NNSA, and the University are under way to revamp and improve the process currently embodied in Appendix F to the contract. The cornerstone of the new Appendix F process—targeted to be in place for FY 2003—will be nine major goals that represent key deliverables in programmatic, scientific, and operational areas.

4.1 Environment, Safety, and Health (ES&H)

Livermore's goals are that ES&H be integrated into programmatic and support activities as a top priority and executed in a cost-effective manner, that Laboratory operations be conducted in an environmentally responsible manner, and that ES&H performance be comparable to the best of our peers.

We expect to meet high standards of ES&H performance within our current operations budgets. To achieve our ES&H goals, our Laboratory culture must place high priority on ES&H as both a line-management responsibility and an individual responsibility. ES&H must be fully integrated into all

Laboratory activities, with appropriate balance between risk acceptance and costs.

Most accidents are preventable through close attention to potential hazards and diligence by each individual and responsible organization. It is of paramount importance that employees take responsibility for making the Laboratory a safe place to work and that the community sees us as a good neighbor, concerned about safety as well as health and the environment.

Situation and Issues

Integrated Safety Management. The Laboratory policy is that safety of both workers and the public is a priority consideration. Although we work with hazardous materials and perform complex operations, our activities must be conducted safely, with full protection given to workers, the public, and the environment.

We want to be recognized as an institution capable of carrying out challenging projects and state-of-the-art research and development in a safe manner. To this end, we have implemented DOE's ISMS in all aspects of Laboratory operations. The central themes of integrated safety management are that each individual is responsible

for his or her own safety, that work must be authorized before it can proceed, and that anyone can—and should—stop unsafe work practices.

Laboratory-wide ISMS embodies all of DOE's seven guiding principles and five core functions:

Guiding Principles

1. Line-management responsibility for safety.
2. Clear roles and responsibilities.
3. Competence commensurate with responsibilities.
4. Balanced priorities.
5. Identification of safety standards and requirements.
6. Hazard controls tailored to work being performed.
7. Operations authorization.

Core Functions

1. Define the scope of work.
2. Analyze the hazards.
3. Develop and implement hazard controls.
4. Perform work within controls.
5. Provide feedback and continuous improvement.

In addition, as part of Livermore's ISMS, the fundamental guiding safety principle states, "Each employee, supervisor, and manager is responsible

for ensuring his or her own safety and promoting a safe, healthful, and environmentally sound workplace and community."

Environmental Management.

Livermore's *Site Annual Environmental Report*, prepared each year by the Environmental Protection Department, summarizes the results of environmental monitoring and provides an assessment of the impact of Laboratory operations on the environment and the public. In addition to fulfilling our responsibilities to employees and neighboring communities, we must ensure that Laboratory programs comply with the National Environmental Policy Act (NEPA), the California Environmental Quality Act, and related federal and state requirements.

Direct funding for environmental restoration and waste management at the Laboratory is shown in Table 4-1. Environmental protection efforts include environmental monitoring, permitting and reporting, natural and cultural resources risk assessment, and analysis as well as major endeavors in environmental restoration—principally groundwater cleanup—and hazardous waste reduction and disposition. In the area of environmental remediation, considerable work has been done to

Table 4-1. Direct funding for Environmental Restoration and Waste Management Program plans and initiatives, including capital funding (millions of dollars, \$M).

	FY 2001	FY 2002	FY 2003 ^a	FY 2004 ^b	FY 2005 ^b	FY 2006 ^b	FY 2007 ^b	FY 2008 ^b
Waste Minimization and Pollution Prevention	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.0
Environmental Restoration	22.8	19.5	22.8	24.8	26.0	26.1	25.0	22.0
Waste Management	20.6	22.9	30.4	29.9	31.2	32.3	33.6	34.9

^aSubject to final budget resolution.

^bProjected resources FY 2004–2008

clean up soil and groundwater contamination at the Laboratory's main site and Site 300 to meet community interests and satisfy regulatory requirements under Federal Facility Agreements. Both sites are on the Superfund list. At the main site, we have successfully removed much of the buried materials as well as reduced areas of contamination by using traditional and innovative soil-vapor and groundwater treatment systems. With these techniques, we have pulled back the contaminant plume to within the Laboratory's property line in the shallow groundwater zones. If adequate funding is provided, we are ready to operate existing facilities and complete the construction of the final treatment facilities necessary to maintain control of all contaminant plumes by 2007.

Strategy Thrusts

Consistent Practices through ISMS.

ISMS implementation is a steady-state effort at the Laboratory—not a one-time event. With ISMS in place, consistency and accountability in ES&H practices across the Laboratory will help us to meet safety goals while achieving cost efficiency. We will also work to strengthen ISMS by addressing opportunities for improvement and solidifying the ES&H enhancements that have resulted from implementation of ISMS. Particular attention will be paid to three areas in which opportunities for improvement were identified by the DOE Verification Team.

Through ISMS, we have established Laboratory ES&H policy guidelines and procedures that enhance accountability. Practices that are followed at high-performance, private-sector R&D organizations were studied as a guide. A major focus has been on better defining and articulating the flow of responsibility

in Livermore's matrix management system. We have also reviewed our system of rewards and discipline for ES&H to assure consistency, promote safety, and better deal with safety violations and poor safety performance.

As a part of ISMS, work activities are formally reviewed and authorized before work begins, consistent with the work planning and authorization process. In addition, the Laboratory's *ES&H Manual* has been updated and reorganized to a structure better aligned with ISMS. Activities to implement ISMS have led to more consistent, clear communication of expected safety practices and effective training. Clearly defined roles and responsibilities have been formalized through memoranda of agreement between organizations and facilities. These agreements, which are particularly important issues for the Laboratory's nuclear and other hazard-ranked facilities, delineate communication protocols, maintenance responsibilities, and reporting requirements.

Remediation and Restoration. We will continue activities to better characterize and clean up hazardous materials and contaminated groundwater at the Livermore site and Site 300. In these efforts, we will continue to develop, test, and deploy innovative solutions that have broad application to environmental problems at other contaminated sites. We have made considerable progress in environmental remediation and restoration of the Laboratory, but much work remains.

However, future budget prospects are uncertain. Potential reductions would result in a funding level that is inadequate to meet the currently negotiated Federal Facility Agreements under the Comprehensive Environmental Response Compensation and Liability Act. With \$22.8 million in FY 2003, we

expect to continue operating the existing Livermore site treatment infrastructure to maintain hydraulic control of plumes and prevent them from moving offsite. Also, additional extraction wells and treatment facilities will be constructed to establish build-out of the remediation system. At Site 300, we expect to reduce our effort to understand the movement of contaminants in groundwater, but existing treatment systems will be operated to prevent plumes from moving offsite. The Laboratory is also assisting DOE to prepare a plan for accelerating cleanup of both the Livermore site and Site 300. The plan is the result of a top-to-bottom review of DOE's complex-side environmental management program commissioned by DOE/EM-1.

Cost-Effectively Reducing and Managing Waste. Efforts are continuing to focus on the use and further development of cost-effective technologies and acceptable methods for pollution prevention as well as for waste reduction and management. Beginning in FY 2003, DOE/EM will no longer fund Livermore's pollution prevention and waste minimization (P2/WM) program. Continuing efforts to develop cost-effective technologies and acceptable methods, which focus on both technical opportunities and the need to reduce costs, will depend on institutional support.

As for waste management, facilities and waste-handling operations are managed to minimize the impact on the environment and to maximize the efficient use of environmental management operating funds. We strive to continually improve efficiency and reduce waste inventory as we operate Livermore's waste facilities. We have been successful in our efforts over the last five years to reduce waste management costs. However, increases

in DOE and regulatory requirements and budget constraints make it increasingly difficult for the Laboratory to sustain waste-management operations that are more than minimally compliant.

Disposition of legacy wastes continues to be problematic. An inability to move transuranic (TRU) waste inventory at the Laboratory to the Waste Isolation Pilot Plant (WIPP) in New Mexico increases both the costs and risk of our operations. Livermore currently has an opportunity to use the WIPP mobile vendors for certification of the TRU waste inventory in FY 2003, thereby allowing shipments of TRU to begin in 2003 and be completed by 2004. If this opportunity is missed, shipments could be delayed for a long time due to WIPP access issues, and we may have to curtail some operations that provide vital support to our national security programs. We continue to pursue the needed funding for disposition of all of the Laboratory's legacy low-level waste.

Waste management operations would also greatly benefit from effective use of our new \$62-million Decontamination and Waste Treatment Facility (DWTF) with its improved safety systems. Operations have started in the warehouse area of the DWTF but not yet in the treatment plant for liquid radioactive waste. DOE is completing review of the safety analysis report, and operations are expected to begin in 2003.

4.2 Laboratory Security

Protection of sensitive information, nuclear materials, and other valuable assets at the Laboratory is a critically important aspect of responsible operations. Effective protection depends on the efforts of the Laboratory's

safeguards and security professionals, computer security experts, program security officers, computer system administrators, and counterintelligence specialists as well as the proper training and vigilance of all employees.

We take security very seriously at Livermore and have greatly expanded our efforts since the events of September 11, 2001. An extensive apparatus is in place at our Laboratory, and we continually make adjustments and upgrades to address new threats and concerns. Protection is provided by employing increasingly sophisticated measures in a cost-efficient manner through a triad of security—physical security, computer security, and counterintelligence.

Physical Security, based on a series of defensive layers and access control, is implemented by our Safeguards and Security Program. We take a graded approach to physical security in which physical barriers (e.g., fences, doors, repositories, and vaults) and permitted access are increasingly stringent, depending on the value or sensitivity of the asset.

Computer Security provides protection of the Laboratory's electronic information, computers, data networks, and telecommunications systems in a world that is growing ever more interconnected and dependent on the transfer of digital information. The mission of the Computer Security Program (CSP) is to ensure the protection of information and computing resources at a level commensurate with the assessed risk and the value and sensitivity of the resources, as determined by the Laboratory's line managers.

CSP is involved in all aspects of Livermore computer security, including security architecture development; the

implementation, deployment, and operation of the security infrastructure; policy development and implementation oversight; and compliance validation. Our computer security experts incorporate Laboratory requirements, best business practices, and DOE orders relating to computer security to create a balanced computer security program. CSP also coordinates training on computer security issues and provides capabilities in threat analysis, incident response, and computer security forensics.

Counterintelligence at the Laboratory is the responsibility of the Security Awareness for Employees (SAFE) Program. SAFE was formed in January 1986 in response to a Presidential Decision Directive dated November 1, 1985, that required all U.S. government agencies to establish their own counterintelligence programs. SAFE's purpose is to identify and counter foreign intelligence threats against Laboratory personnel, information, and technologies.

Situation and Issues

Security Challenges of the 21st Century. A major challenge facing the Laboratory is to protect the staff and sensitive information and technologies as we participate in an increasingly global scientific and technical community. As a national security laboratory, Livermore is a work environment for over 8,000 people and a repository of sensitive and classified information, special nuclear materials, and other valuable government property. In the ongoing war against terrorism, the people and physical assets of the Laboratory are potential targets and must be protected accordingly. At the same time, access by non-Laboratory employees to many of Livermore's

facilities is necessary. We work in partnership with universities, industry, and other laboratories on many unclassified projects. More generally, we are part of the international science and technology community and depend on interactions with others to be cognizant of major advances and to acquire special expertise needed to accomplish mission goals.

Heightened Awareness of Security

Issues. Security depends on the vigilance of everyone—from senior managers to individual employees. Workers are trained to be aware of potential terrorist threats against the Laboratory as well as severe consequences of security violations that place nuclear secrets at risk. Staff awareness of security issues and foreign intelligence-gathering efforts at the NNSA laboratories is very much heightened as a consequence of the attacks on the U.S. and the highly publicized security incidents in 1999 and 2000.

We rely on a comprehensive Safeguards and Security Awareness Program at the Laboratory to understand the threats that we face and to be properly trained in responsibilities, proper procedures, and best practices. In addition to a series of DOE mandatory briefings—many of which are annual requirements—the Laboratory offers nearly a dozen additional programs, some of which train people for specialized security responsibilities. Each year, employees are required to complete security refresher training, and those who do not complete it or fail the follow-on test have their clearances suspended or revoked.

An Extensive Security Apparatus. An extensive security apparatus is in place at Livermore. In the area of physical security, our defense-in-depth approach

includes a system of clearances, badging, and background checks; physical barriers and access control to protect sensitive and classified assets; and a fully trained and accredited security force. Since the September 11 terrorist attacks, Livermore's protective service officers have operated on a heightened state of alert, taking additional measures to make sure that the Laboratory is safe and secure. In addition, a vigorous Operations Security (OPSEC) Program serves to identify potential "open" pathways to sensitive information in Laboratory operations and recommends cost-effective countermeasures to deny exploitation.

A defense in depth also characterizes computer security at the Laboratory. Our classified computer and unclassified computer networks are totally separate. All systems connected to the classified system are secure, and access to information on the classified system is on a need-to-know basis. For unclassified computers connected to the outside world, we provide protection against intrusion, monitor traffic, and respond to incidents. Moreover, DOE's Computer Incident Advisory Capability (CIAC) provides on-call technical assistance to DOE sites and other government agencies facing computer security incidents, such as break-ins, attempted break-ins, viruses, and scans by outsiders.

Livermore's counterintelligence program, SAFE, was established in 1986 and has grown in response to the Laboratory's increasing number of foreign interactions, particularly lab-to-lab programs. SAFE—largely staffed by former Federal Bureau of Investigation (FBI) special agents—works closely with the FBI and is well integrated into the U.S. counterintelligence community.

Our security performance is currently

rated satisfactory (the highest rating) by DOE's Office of Independent Oversight and Performance Assurance. Similarly, the Laboratory received a satisfactory rating in all security areas from the DOE/NNSA Oakland Operations Office for the review period ending June 30, 2001. Nevertheless, security requires vigilance, and we continue to make upgrades to strengthen all aspects of security, address identified issues, and deal with perceived weaknesses.

Strategic Thrusts

Integrated Safeguards and Security Management (ISSM). In March 2001, NNSA introduced ISSM as an initiative to strengthen the partnership of science and security to carry out the national security mission. At Livermore, the development of an ISSM system designed to meet our needs is a key part of our efforts to constantly strengthen security at the Laboratory. In developing ISSM, we are focusing on enhancing security mechanisms already in place. One objective is to improve our ability to systematically integrate all aspects of security into management and work practices at all levels. Another is to streamline processes and procedures where possible. The implementation of ISSM is complementing our efforts to maintain a modern and effective security program at Livermore, and it will demonstrate to the nation our commitment to a strong security system at the Laboratory.

Livermore's ISSM system is being developed based on the framework for ISSM issued by NNSA. That framework provides a set of NNSA components for the Laboratory to use in creating its system. An overarching goal for ISSM is for all employees to be fully aware of and understand the Laboratory's security program and requirements. We have

introduced an ISSM system that:

- Provides employees clearly defined security roles, responsibilities, and expectations.
- Defines expectations for the work being done.
- Focuses on security awareness.
- Provides employees with better tools for meeting the security expectations placed on them.
- Assures that all employees understand what needs to be protected and why.
- Fosters in all employees an understanding of the need for continuous improvement and feedback with regard to security.

A two-year timetable was established for implementing an ISSM system at Livermore. The first step in the process included sending to all employees the booklet, *An Introduction to Integrated Safeguards and Security Management for Laboratory Employees* (May 2001). It provides the principles, goals, and functions of ISSM as well as information about the process and timetable for developing the ISSM system. An early goal of ISSM development has been to engage the workforce in providing feedback on security procedures and practices. This has been done through a series of focus groups. The feedback was an important element in developing a gap analysis and subsequent action plan for implementing improvements. Initiatives in the action plan are nearing completion, and Livermore expects to have the foundational elements of ISSM in place by December 31, 2002.

Effective Physical Security. The Laboratory regularly prepares a comprehensive Site Safeguards and Security Plan, predicated on the DOE Design Basis Threat, that details the computer, physical, and procedural measures we are taking. In general, the

physical security of the Livermore site (and Site 300) is maintained through a multilevel, graded approach to limit access and protect information. The Laboratory is compliant with all DOE security requirements. In addition, in response to evolving security requirements, the Laboratory continues to make physical security improvements. All NNSA sites, including Livermore, have reevaluated the physical security of facilities to develop a prioritized list of upgrades in anticipation of increased NNSA funding to counter the threat of terrorism.

We also continue to pursue technological innovations, such as sophisticated detection systems and the automated portals developed at Livermore to minimize costs. Our automated portal system (Argus) has been adopted as a DOE standard and is being installed at other facilities.

East Avenue Closure. We are taking steps to deal with a long-standing issue—the physical proximity of East Avenue. The road runs between Lawrence Livermore and Sandia/California, and both laboratories have significant facilities close to it. Controlled access to East Avenue would provide enhanced security for facilities and personnel. We have DOE, political, and public support for moving forward on the closure of East Avenue. Alameda County, the City of Livermore, and our neighbors are receptive to the proposal, and we are looking at methods to fast-track the project. NNSA has given the project high priority and is providing funding for a conceptual design. Our long-term goal is to relocate public involvement activities to the west outer perimeter of the Laboratory, including new facilities for visitors, as well as science and education outreach activities.

Attention to Security Procedures for Foreign Interactions. Physical security measures are augmented by a system of security controls that apply to day-to-day operations. Specific issues that are raised by foreign nationals' visits to and assignments at the Laboratory, as well as sensitive foreign travel by our staff, are addressed on a case-by-case basis. A foreign visit or assignment involving a sensitive country, a sensitive facility, or sensitive information undergoes careful individualized scrutiny, and it requires completed indices checks, a review for sensitive unclassified information, and an individual security plan. Other visits and assignments are conducted through a standard security plan.

Highest Standards of Computer Security. Revolutionary changes have occurred in information technologies. For example, portable hard drives can hold gigabytes of data, orders of magnitude more information than the Laboratory's mainframe computers of the 1970s. Concerns about the implications from espionage involving computer-based information and codes have spurred a thorough reassessment of computer security at the NNSA laboratories and a well-defined program to enhance computer security. Additionally, we are using our computer security upgrade as an opportunity to apply our multidisciplinary approach to science and technology to become a model for computer security.

Significant improvements made to our computer security in the last two years include policy development, technical integration of intrusion detection and reaction capabilities, an information security architecture, a computer-systems vulnerability scanning and remediation program, a significantly improved institutional firewall capability, improved computer-security training, new

procedures and requirements regarding the transfer of classified information within an office, intrusion detection on classified systems, institutional computer virus protection, and implementation of an unclassified three-level network architecture. In a stand-alone evaluation of computer security in February and March 2001, DOE's Office of Independent Oversight and Performance

Assurance (OA-20) rated our classified and unclassified computer security programs as "Satisfactory." Again in February and March 2002, the DOE/OA conducted a follow-up review of the computer security program to evaluate the status of corrective actions developed as a result of the 2001 OA computer security assessment. The OA concluded that Livermore made significant progress

in correcting past findings and implementing opportunities for improvement from the last OA inspection. The classified program was rated as "Effective Performance"; the unclassified program was not rated. In both years, the ratings were the highest possible.

A Vigorous Counterintelligence Program. Our counterintelligence

Table 4-2. Laboratory staff composition as of March 31, 2002 (excludes summer hires and temporary program participants; may include indefinite employees).

		Management		Scientific		Administrative		Technical		Others		Total	
		No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
White	M	785	(63.4)	1,436	(69.3)	140	(22.7)	1,033	(63.7)	454	(33.1)	3,848	(55.6)
	F	256	(20.7)	264	(12.7)	336	(54.5)	262	(16.2)	501	(36.6)	1,619	(23.4)
Black	M	27	(2.2)	23	(1.1)	11	(1.8)	45	(2.8)	45	(3.3)	151	(2.2)
	F	14	(1.1)	12	(0.6)	19	(3.1)	13	(0.8)	41	(3.0)	99	(1.4)
Hispanic	M	42	(3.4)	48	(2.3)	8	(1.3)	110	(6.8)	110	(8.0)	318	(4.6)
	F	32	(2.6)	15	(0.7)	30	(4.9)	17	(1.0)	100	(7.3)	194	(2.8)
Indian	M	15	(1.2)	6	(0.3)	4	(0.6)	21	(1.3)	20	(1.5)	66	(1.0)
	F	4	(0.3)	0	(0.0)	8	(1.3)	9	(0.6)	12	(0.9)	33	(0.5)
Asian	M	35	(2.8)	174	(8.4)	18	(2.9)	70	(4.3)	41	(3.0)	338	(4.9)
	F	25	(2.0)	55	(2.7)	38	(6.2)	19	(1.2)	32	(2.3)	169	(2.4)
Total minority	M	119	(9.6)	251	(12.1)	41	(6.7)	246	(15.2)	216	(15.8)	873	(12.6)
	F	75	(6.1)	82	(4.0)	95	(15.4)	58	(3.6)	185	(13.5)	495	(7.2)
Unidentified	M	3	(0.2)	37	(1.8)	1	(0.2)	19	(1.2)	5	(0.4)	65	(0.9)
	F	1	(0.1)	2	(0.1)	3	(0.5)	4	(0.2)	9	(0.7)	19	(0.3)
Totals	M	907	(73.2)	1,724	(83.2)	182	(29.5)	1,298	(80.0)	675	(49.3)	4,786	(69.2)
	F	332	(26.8)	348	(16.8)	434	(70.5)	324	(20.0)	695	(50.7)	2,133	(30.8)
Lab totals		1,239		2,072		616		1,622		1,370		6,919	

Table 4-3. Laboratory staff composition by education as of March 31, 2002 (excludes summer hires and temporary program participants; may include indefinite employees).

	None	AA	BA/BS	MA/MS	PhD	Total population
Management	287	112	232	245	363	1,239
Scientific professional	29	6	577	589	871	2,072
Administrative professional	245	44	216	95	16	616
Technical jobs	817	524	259	21	1	1,622
Other jobs	1,110	172	82	6	0	1,370
Totals	2,488	858	1,366	956	1,251	6,919

program (SAFE) develops threat assessments for the Laboratory, reviews visits and assignments by foreign nationals, and runs a vigorous Laboratory-wide counterespionage awareness program. SAFE was identified as a model for similar programs throughout DOE in a review of the program by DOE's head of counterintelligence in April 1998.

We continue to improve SAFE's capabilities so that the Laboratory's security measures stay ahead of increasingly challenging espionage threats. For example, we have installed the Visitor Tracking System for use at Livermore. Information on each foreign visit and assignment is entered into the system as part of the review and approval process. The database automatically captures numerous pieces of information about each visit and assignment and can provide statistics as needed. A similar system has been developed and is used for employees who go on official travel to foreign countries.

We also continue to upgrade our extensive employee espionage awareness programs. The SAFE staff provide briefings and debriefings for personnel who host foreign visitors or travel abroad and sponsor Laboratory-wide presentations on espionage-related topics by guest speakers from the U.S. intelligence community.

Human Reliability Programs.

Livermore has implemented two human reliability programs to assure that individuals with access to special nuclear materials or nuclear explosive devices and components meet the highest standards of reliability. The Personnel Security Assurance Program (PSAP) for individuals with access or who guard special nuclear explosives and the Personnel Assurance Program

(PAP) for individuals with access to nuclear explosives devices and components provide another level of review and a higher standard of performance than the DOE Access Authorization process. These individuals must undergo annual physical and psychological evaluations, random drug testing, polygraph testing, training in the recognition of security concerns, and close supervisory oversight before being authorized to perform these duties. About 7 percent of the Livermore employee population is in one or the other of these two programs.

4.3 Laboratory Personnel

Livermore's principal asset is its quality workforce. The Laboratory seeks a highly talented, productive, motivated, flexible staff that is committed to Livermore's goals and reflective of the diversity of California and the nation. We strive for a work environment in which all employees can contribute to their fullest and feel valued for their role. The size, job classification, and diversity of Livermore's career-employee workforce are characterized in Tables 4-2 and 4-3.

We value the dedicated efforts of our entire workforce in contributing to the scientific, technical, operational, and administrative success of the Laboratory. Breakthrough accomplishments are critical to the success of Livermore's programs and provide the foundation for future programs to meet national needs. These accomplishments are only possible in an environment with safe and efficient operations. In all of our activities, we recognize and reward both individual and team excellence in performance. All employees are encouraged to take pride in and

responsibility for their work, improve their skills, and continue their professional growth.

Situation and Issues

Strong Bond with the University of California. The contract between DOE and the University of California to manage the Laboratory is critically important to our continuing ability to recruit and retain an outstanding workforce. For the technical staff, the Laboratory provides challenging scientific programs, world-class research facilities, and creative research opportunities plus the association with the University of California that has led to an array of scientific and technical ties to academia that would not have been possible otherwise. More generally, all employees have the opportunity to work in a collegial atmosphere with talented peers to solve difficult problems of national interest.

The strong bond between Livermore and the University nurtures an atmosphere at the Laboratory in which independent views and technical honesty are core values. University of California management of Livermore also provides employees an excellent benefits package and a policy framework for the Laboratory's human resources program.

The Laboratory, in concert with the University, is instituting a multiple-location program that will make it easier for staff to work concurrently at more than one UC location without affecting employee service credit and benefits. Additionally, the Laboratory is working with UC, Lawrence Berkeley, and Los Alamos to coordinate specific recruitment efforts that will strengthen our corporate image and maximize our affiliation with the University of California.

Recruiting and Retaining High-Quality Employees. Despite these competitive advantages, Bay Area companies furnish significant competition for the best people, and in many skill areas such as optical engineering, demand far outpaces supply. The Laboratory does not have all the tools available to the private sector (e.g., stock options) to compensate their employees. However, the Laboratory has been successful in attracting and retaining a high-quality workforce because our strength is our work environment, the importance of the national security work, exciting technical challenges, career development, and educational opportunities. The Laboratory's compensation system is structured to recognize superior performance and is driven by the market.

A Skilled and Flexible Workforce. The Laboratory continues to focus on the goal of the employee population having the motivation, innovation, and diversity needed to excel in its mission. Current initiatives include a focus on career development for all employees through institutional guidelines as well as increased training programs for supervisors and employees. In addition, a variety of flexible work schedule options is offered to further enhance recruitment and retention.

Strategy Thrusts

Workforce Survey Implementation.

Over the last several years, Livermore has been affected by many workplace issues: increased competition for quality employees, increased external oversight, and new policies and procedures regarding safety and security. To better and more systematically understand the issues facing employees and to assess their views, the Laboratory conducted a

formal survey of employees' opinions in June 2001. The survey, *Assessing the Workplace*, was developed through close interactions between Laboratory staff and a leading survey firm. Questions focused on issues such as job satisfaction and work environment; growth opportunities, career development, and retention; diversity and equal opportunity; and overall management of the Laboratory.

The survey results were used to measure broad Laboratory views, identify employee priorities, and identify specific issues and potential solutions. By better understanding key workplace issues, the Laboratory is able to more effectively respond to the needs of the increasingly diverse workforce of the 21st century. Survey action teams were formed and made recommendations for improvements in seven focus areas identified through the survey:

- Salary and compensation.
- Training and career development.
- Performance management.
- Work/life balance.
- Employee empowerment.
- Technicians and facilities support workers.
- Postdoctoral fellows.

The action teams were staffed by 10 to 12 employees from across the Laboratory with support from Human Resources and other organizations where appropriate. Their work was finished in February 2002.

Laboratory senior management recommended immediate attention and implementation in many areas, notably:

- Improving the Laboratory's performance management system.
- Investing in career development programs.
- Promoting organizational values, rigorous debate, and civility.
- Maintaining a competitive total rewards program.

- Expanding flexible work schedule options.
- Expanding availability of work/life services.
- Increasing opportunities to participate in innovative research and development work.

The Survey Action Team Implementation Project has begun implementing these recommendations. Many have been implemented in FY 2002, with the remainder to be implemented in FY 2003.

Recruitment and Retention. As with many other employers, we are finding that recruitment and retention are major issues for the Laboratory. Our goal is to ensure that our ability to attract and retain employees remains competitive for the type of skills we need. To that end, we will use the results of the workforce survey to review policies and practices related to human resource functions and take actions to enhance the Laboratory's overall collegial work environment.

The highly competitive labor market of the Bay Area continues to be a challenge to our recruitment and retention efforts, particularly in the "hot" skills. We monitor regional as well as national compensation practices and have taken steps in recent years to boost our competitiveness for these needed skills. The Laboratory's Employee Referral Bonus Program has proven to be an effective tool in increasing the number of qualified applicants for hard-to-recruit and mission-critical positions. Additionally, the housing per diem instituted for student interns has enhanced our pipeline recruitment efforts.

Focus on Employee Well-Being.

Saving employees time and helping employees to get to know and trust one another is a fundamental objective of

the Employee Services Association (LLESA). The Association is a key element of the Laboratory's recruitment, retention, and diversity plans. LLESA plays a pivotal role in increasing workforce unity, keeping employees connected, promoting employee health and well-being, and fostering employee communication and cooperation. LLESA and the Laboratory will continue to identify services that will keep the Laboratory attractive to prospective employees and its contemporary workforce.

Attention to Workforce Diversity. The Laboratory reorganized its Human Resource functions into two separate departments: (1) Staffing and Employee Development and (2) Compensation, Benefits, and Work–Life. Diversity and affirmative action efforts are now integrated directly into both departments to recognize its importance to all aspects and responsibilities of recruitment, hiring, benefits and pay, and employee development services. (Previously there was a separate Affirmative Action and Diversity Program [AADP].) A refocused Diversity Programs Office (DPO) is leading the implementation of diversity programs with the goal of creating a rewarding and hospitable work environment for all employees. DPO develops the Laboratory's action plans to increase diversity, sponsors a variety of outreach programs, and interacts with employee network groups to foster strong working relationships among these diverse associations. DPO also provides funds to these groups to promote cultural awareness and support for scholarship funds.

To promote Livermore as an employer of choice, DPO staff members participate in conferences for recruitment and educational purposes, support collaborative partnerships, and cosponsor

scholarships with external organizations. The Laboratory also supports local and national service and community-action programs that improve employment opportunities for women and minorities. These outreach activities aim to help the Laboratory meet immediate and future hiring needs by reaching the broadest population, thus ensuring that all employment pools are diverse and represent the population available in specific career areas. For a summary of DPO's broad range of activities, refer to its Website, <http://www.llnl.gov/aadp/>.

More generally, the annual workforce plans that are developed and implemented at the Laboratory consider both programmatic needs and institutional goals, such as achieving a workforce that is reflective of the rich diversity of California and the nation. It is essential that the Laboratory develops and maintains a diverse workforce and provides employees and applicants for employment with a discrimination-free workplace.

Employee Development. The Laboratory continues to place an emphasis on the development of its employees through a robust education and training program. Institutional support for undergraduate and graduate degrees is provided through the Tuition Assistance, Undergraduate Scholarship, and Advanced Study Programs. In addition to established distance learning programs and on- and offsite education and training courses, desktop delivery of both technical and professional content is a major thrust. The Continuing Education Committee provides guidance for these programs to meet current workforce technology needs.

Leadership and Management Development. A particular area of emphasis for the Laboratory is training for supervisors and managers. We have a

set of core courses for supervisors and managers: Supervision I for new supervisors, Supervision II for all supervisors, and the Management Institute for division leaders and above. These programs are designed to assure that all supervisors and managers understand their full responsibilities, including Laboratory policies and procedures, and develop solid leadership and people skills. Senior managers are actively involved in the design and implementation of these programs and serve as the faculty for Supervision I and the Management Institute.

The Laboratory's comprehensive management development strategy is distinguished by four cornerstones:

- Curricula that meet Laboratory needs. Curricula range from an institute to prepare the next generation of Laboratory leaders to popular management lectures for all employees. Core competencies have been identified to better guide current and developing leaders. Programs are presented in venues that include core courses, briefings and short courses, lecture series, open enrollment courses, directorate-specific leadership programs, and recommended externally offered management courses.

- Management commitment. Across the Laboratory, senior management commitment is demonstrated by a high level of participation in the design, implementation, and instruction of the programs.

- Relevance and practicality. Programs, courses, and briefings are targeted at specific Laboratory issues—leadership and succession, performance management, and career development. Maximum relevance and value are sought from a strategic blend of custom-designed courses, external vendors, and in-house experts.

• Improved succession programs. Laboratory-wide as well as directorate-specific programs have been developed to increase the number and quality of candidates to be the next generation of Laboratory leaders.

Other Workplace Improvements. In response to the 2001 employee survey and identified training needs, the following management development efforts are under development: supervisory training for employee career development, implementation of flexible work schedules, and performance management training. We anticipate the continuation of specific directorate programs to develop succession pools. The addition of new courses such as Accountability Management, Strategic Thinking, and Building Effective Teams will enhance the curriculum. Also under consideration are pre-supervisor courses and the use of assessment and coaching as development tools.

Table 4-4. Laboratory space distribution.

Type of space	Area in 1000s of	
	Square feet	Square meters
Main site ^a	5,700	530
Leased—university	3	0
Leased—offsite	74	7
Site 300	400	37
Total	6,177	574

^aIncludes tents; OSF not included.

4.4 Facilities and Plant Infrastructure

Lawrence Livermore National Laboratory is composed of two sites: the main Livermore site and Site 300, a 28-square-kilometer remote explosives test facility located about 25 kilometers southeast of Livermore. The Livermore site has 180 permanent buildings and 248 temporary structures and houses over 9,000 people. At Site 300, there are 102 permanent buildings and 36 temporary structures (Table 4-4.)

The combined replacement plant value of both sites for buildings, trailers, and other structures as well as utilities and infrastructure is estimated to be \$3.5 billion (Table 4-5). In addition, personal property has a purchase price of \$1.65 billion, of which personal property items subject to inventory (attractive items and/or property—including trailers—with purchase prices over \$25,000) are valued at \$815 million.

Stewardship of DOE lands and facilities at Livermore is an important responsibility. We have world-class scientific facilities that are essential for national security and provide unique capabilities to meet other enduring national research and development needs. Facilities and infrastructure—and our investment strategy for maintenance, renovation, and new construction—must be aligned with the Laboratory's programmatic and operational requirements.

We want every employee to take pride in Livermore's campus setting—

a physical plant that is attractive, accessible, and designed to be cost effective and inviting. This goal requires modern facilities at the Laboratory, designed and sized for current and future operations and well maintained at competitive costs. A quality campus environment attracts top-notch employees, enhances workforce productivity, and helps ensure programmatic success.

The challenges we face stem from our expectation of insufficient new office construction in the near term and the need for sufficient resources to achieve our goal through site revitalization. As described in the *Laboratory's FY 2003 Ten Year Comprehensive Site Plan*, our strategy includes a balanced set of efforts to rehabilitate older facilities, consolidate activities as mission priorities change, maintain mission-critical aging facilities, and efficiently manage legacy facilities.

Situation and Issues

New Construction. Unique, state-of-the-art, experimental research facilities are a core strength of the Laboratory. As described later in Facility Plans and Resource Requirements, several of the major national security directorates have some new modern core facilities in planning or under construction. Additionally, construction is continuing on the National Ignition Facility, which will be a cornerstone of the nation's nuclear weapons Stockpile Stewardship Program. In FY 2002, construction was started on two major facilities:

- The Terascale Simulation Facility, to house the Laboratory's ASCI computers and provide needed office space for the program.
- The International Security Research Facility, which consolidates nonproliferation and intelligence-related operations and updates needed

Table 4-5. Facilities replacement value (in \$M).

	Buildings	Trailers	Other structures	Utility/infrastructure	Total
Livermore site	2,152	84	4	993	3,233
Site 300	164	1	15	110	290
Total	2,316	85	19	1,103	3,523

infrastructure for digital communication.

The modern office space designed into these research facilities—and the space in other recently constructed facilities at the Laboratory—helps to improve the overall living conditions of the Laboratory population.

Rehabilitation and Replacement.

Strategic management of Laboratory facilities must balance the needs and resources for maintenance, facility rehabilitation, and new facilities development. Many structures are 30 to

50 years old (Figure 4-1). They are particularly demanding for maintenance to keep them adequate, and over time, all will need rehabilitation or replacement. Only 68 percent of our employees currently reside in permanent space, and the majority of temporary office space (55 percent, down from 65 percent after recent reinvestments in World War II–era buildings) is nearing or already beyond the end of service life. As more facilities age substantially beyond their intended life, our need for

modern office space will continue to grow. Figures 4-2 and 4-3 show the current condition of Laboratory space.

The health and safety of employees are of primary importance to the Laboratory. Any facility that poses a risk in this regard is vacated, rehabilitated, or removed, and the occupants are relocated. In addition, from long-discontinued programs, we have outdated and unusable laboratory space that must be decommissioned, decontaminated (where necessary), and/or demolished. Livermore's legacy facilities and other excess marginal space require considerable investment to rectify (e.g., clean up, rehabilitate, reconfigure for a different use [adaptive reuse], or remove).

To efficiently manage our older facilities, site planners use a scoring system of 0 to 4 for 12 criteria to identify facility candidates for rehabilitation or removal. The system, referred to as the Facility Assessment and Ranking System (FAaRS), helps us prioritize institutional requirements to keep our mission-essential aging facilities operational and in adequate condition. Prompted by FAaRS, the Laboratory has made significant reductions in substandard space in recent years, by removal,

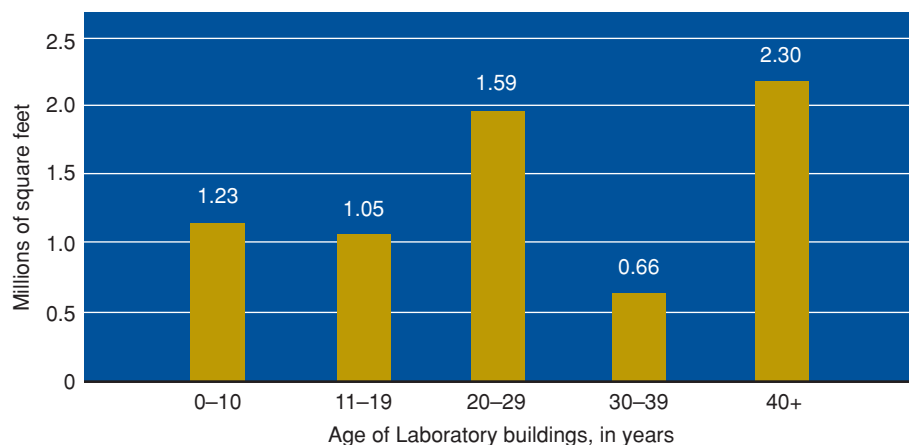


Figure 4-1. Age of Laboratory buildings.

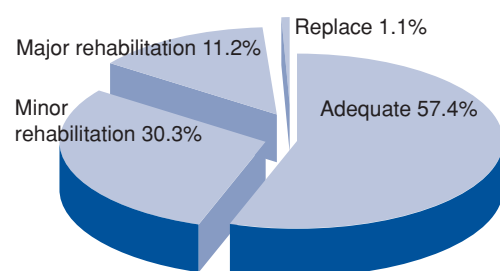


Figure 4-2. Condition of Laboratory space.

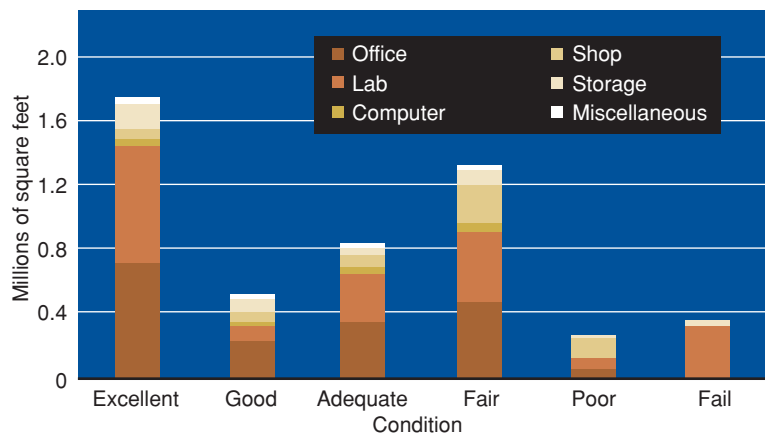


Figure 4-3. Use and condition of Laboratory space.

rehabilitation, or mothballing (Table 4-6).

Maintenance Management. Through the process of the Cost Cutting Initiative in 1997, the Laboratory identified serious deficiencies in facilities and infrastructure due to underinvestment. The existing maintenance backlog was over \$200 million, but it was not clear whether that figure was an appropriate measure of the health of the facilities. The investment required to stabilize the condition of the nominal 6 million square feet of buildings and all the associated utilities was unknown; however, enough was known to begin fixing the most important systems needed to pursue the Laboratory's mission. The Institutional Facility Manager (IFM), a newly created position, was delegated the responsibility to manage these investments.

To better understand and evaluate maintenance investments, we developed a model for planning and tracking actions to reduce the backlog. This model captures—and categorizes according to funding priority classes—the historical backlog, growth to the maintenance list as issues arise as well as correction of deficiencies and (not-to-be-funded) maintenance items in excess facilities. All sources of funds are considered, including those for routine

maintenance and repair; line items; General Plant Projects (GPP); General and Administrative (G&A); programmatic investments in facilities and infrastructure; demolition; and dedicated maintenance reinvestment from a Laboratory Facility Charge (LFC) that is levied on building “owners” based on the gross square footage of their facilities. The LFC provides funds to operate and maintain the Laboratory's facilities and infrastructure.

Through use of a system that tracks maintenance items and their priority as well as expected funding in all categories, we are able to develop estimates of the annual rate of backlog growth and average project cost relative to the backlog estimate. Each year, progress was documented and projections were developed for backlog behavior for the next three to five years. We have now used the system for five years and in the process established credible ranges for the system's parameters. With the effectively targeted investments made since 1997, the growth of backlog has been arrested. Our efforts have established a credible and verifiable estimate of the cost to maintain Laboratory facilities and infrastructure.

Because of the extensive effort in developing, applying, and validating the model, the Laboratory is recognized as a leader in understanding and managing facilities and infrastructure issues within the NNSA complex. The product includes a user-friendly dynamic spreadsheet with associated graphics demonstrating the impact of various funding scenarios. For example, this model provides users effective visual information that makes clear the need to invest in modern facilities while correcting deficiencies in older buildings

that resulted from historical neglect.

The NNSA Facility and Infrastructure Recapitalization Program (FIRP). Many mission-supporting facilities at Livermore and other NNSA sites are nearly 50 years old or older. Some are particularly demanding for maintenance, and over time, all need rehabilitation or replacement. The aging of the NNSA weapons complex was a focus of concern of the Panel to Assess the Reliability, Safety, and Security of the United States Nuclear Stockpile (the Foster Panel). One of the panel's major recommendations was to “restore missing production capabilities and refurbish the complex,” and it cited a DOE estimate that the maintenance backlog was greater than \$700 million.

Motivated by deficiencies within the complex, NNSA launched FIRP, which began in earnest in FY 2002. It is a concerted effort to improve facilities and infrastructure management by instituting better processes for strategic planning, budgeting, and execution—together with funding to make headway on significant issues. A corporate approach was developed to correct the historical neglect to the facilities and infrastructure and to institutionalize the successful processes that were implemented. The Laboratory is actively engaged in executing FIRP projects at Livermore. In addition, NNSA is building on Livermore's experience and adapting the Laboratory's approach to managing maintenance backlog to develop metrics and models for program performance.

Strategy

A Balanced Portfolio for Site

Revitalization. Our objective is to follow a balanced approach in providing facility

Table 4-6. Reduction in substandard space (in 1000s of square feet).

Fiscal year	Space removed
1996	116.8
1997	28.1
1998	22.0
1999	24.9
2000	7.3
2001	27.8
2002	133.8

management to meet programmatic needs, with the goal of assuring the future vitality of the Laboratory and its primary missions. In particular, a coherent Laboratory-wide office requirements plan is continually refined to address the needs of the nearly 4,000 employees who work in trailers, modular units, and World War II-era buildings that we keep operational by using the FAaRS and maintenance backlog ranking processes to prioritize facility investments. Four principal elements of the plan are as follows:

- Construction of new facilities through line items and general plant projects.
- Rehabilitation of older facilities, where cost effective.
- Prioritization and reduction of deferred maintenance backlog.
- Efficient management of legacy facilities.

Our ability to carry out a balanced portfolio for site revitalization depends heavily on both maintenance reinvestment and the FIRP. In addition, Readiness in Technical Base and Facilities (RTBF) within the Stockpile Stewardship Program (see Section 2.1.4) focuses on facilities for particular technical aspects of the NNSA/DP mission. Revitalization of the Laboratory also depends on construction of new facilities (e.g., see earlier discussion about ongoing construction and Facility Plans and Resource Requirements, below).

Infrastructure Recapitalization at

Livermore. The Laboratory is applying FIRP funding to much-needed projects to recapitalize the site, including facility maintenance and restoration, general plant projects, capital equipment, and decontamination and demolition of legacy facilities. Approximately \$26 million of FIRP funding in FY 2002 enabled the Laboratory to begin correcting long-standing

deficiencies in systems, facilities, and infrastructure and to remove some of the excess legacy facilities. The projects include replacement of electrical power systems in aging facilities, building renovation projects, investments in high-efficiency particulate air (HEPA) filters to more effectively ensure that we continue to meet high environmental standards, two decontamination and demolition projects, and a scoping and design study for rehabilitation of a major building complex.

The FIRP is also beginning to substantially reduce the total maintenance backlog by augmenting the Laboratory's ongoing Maintenance Backlog Reinvestment effort, as discussed below. In addition, out-year FIRP projects include the construction of several new office complexes to replace worn-out office facilities.

Maintenance Backlog Reinvestment.

As mentioned, Livermore developed and has been using for the last five years an effective review and prioritization process to ensure the Laboratory's organizations are not significantly affected by lack of essential maintenance to keep facilities safe and reliable. Key to the process are evaluations of the mission impact in the event of a failure and the probability that a specific component or system will fail in the absence of a component or system replacement. The cognizant programs and operating organizations are primarily responsible for evaluating the mission impact of a failure. Primary responsibility for estimating the probability of failure belongs to the Laboratory's Plant Engineering organization, which also is responsible for correcting maintenance deficiencies in work funded through the LFC.

After all projects are given an initial ranking from the joint evaluation, a list

of projects with a rank from A (most critical) to F (no priority) is created and jointly reviewed by the two evaluation teams. Projects that are ranked "A" require immediate attention. Other maintenance projects fall into less critical categories: "B" items are to be addressed within one year and "C" items in less than three years. These three categories constitute the Laboratory's Essential Backlog, representing approximately 20 percent of the total backlog. Lower-priority categories ("D" through "F") are tracked to determine whether they become "essential" or become unnecessary, e.g., when a building is excessed.

Through this process, we have developed and are executing a multiyear institution-wide maintenance backlog management plan. Dedicated maintenance reinvestment funds are allocated annually to correct all the "A" and "B" and the most important "C" deficiencies. As shown in Figure 4-4a, with reinvestments, this process has arrested growth in the total backlog, which has stabilized at about \$200 to \$235 million. The figure also shows that in the absence of FIRP funding to augment the present level of LFC investment, the "essential backlog," now totaling \$44.4 million, is expected to grow to more than \$50 million after FY 2005. However, with the additional funding from the FIRP, the Laboratory will be able to substantially decrease the total and essential backlog (Figure 4-4b).

Figure 4-4b also illustrates that with continued Congressional support for FIRP for the planned ten-year program, the Laboratory will have a backlog equivalent to about a three-year investment in 2012, which is about an ideal state. At that time, we will also have modernized structurally sound older facilities and eliminated legacy facilities. The Laboratory will be in

nominal equilibrium, able to sustain a modern site with our current level of internal funding.

Rehabilitating Older Facilities. To help meet the Laboratory's needs for adequate quality office space as well as service areas, we are rehabilitating and modernizing some of our older facilities. Depending on the return on investment, older but fundamentally sound facilities are being returned to "good, as built" condition by maintenance rehabilitation projects or upgrades by FIRP or newly available Institutional General Plant Project (IGPP) funds. In this connection, we are pursuing workable options for innovative, cost-effective, facility revitalization, and new construction and renovation.

Facility Plans and Resource Requirements

Table 4-7 provides a summary of the Laboratory's funded and proposed construction projects with total estimated cost (TEC) in excess of \$5 million. Construction projects that have recently begun or are proposed to begin in FY 2002 include:

Engineering Technology Complex Upgrade (ETCU) (FY 2002 start, TEC: \$26.7 M). The ETCU project will

revitalize and enhance capabilities of both facilities and equipment and consolidate activities in existing research, prototype fabrication, and metrology in the Building 321 complex. The ETCU project is critically needed for the Laboratory to support the Stockpile Stewardship Program. We must develop state-of-the-art capabilities for fabricating, measuring, inspecting, and testing critical weapon components. The National Ignition Facility will also benefit from the ETCU's new micromachining capabilities. When completed, the ETCU will consolidate manufacturing functions into one contiguous complex, which will improve operation efficiency and production quality, enhance scientific research, and reduce operating costs.

Sensitive Compartmented Information Facility (SCIF) (FY 2001 start, TEC: \$24.6 M). Ground was broken on April 4, 2002, for the new SCIF (named the International Security Research Facility), a two-story 5,900 square-meter building (or 64,000 square feet) to be sited on the west side of the Laboratory, adjacent to and north of Building 132. The new SCIF is essential for the Nonproliferation, Arms Control, and International Security (NAI) Directorate

to continue to carry out its mission by providing major enhancements in information management, optical-fiber networking, storage and retrieval, and real-time communications with DOE and the intelligence community.

Terascale Simulation Facility (TSF) (FY 2000 start, TEC: \$92.1 M). The project provides for the design, engineering, and construction of the TSF (Building 453), which will house future computers required to meet the needs of the Advanced Simulation and Computing (ASCI) Program. The building will contain a multistory office tower with an adjacent computer center. This project is being managed within its baseline cost, scope, and schedule. Ground was broken April 4, 2002, for the 253,000-square-foot facility. From its inception, the TSF has been designed to enable the very large-scale weapons simulations essential to ensuring the safety and reliability of the U.S. nuclear stockpile. The timeline for construction is driven by requirements coming from ASCI within the Stockpile Stewardship Program. The TSF will house the computers, the networks, and the data and visualization capabilities necessary to store and understand the data generated by the most powerful

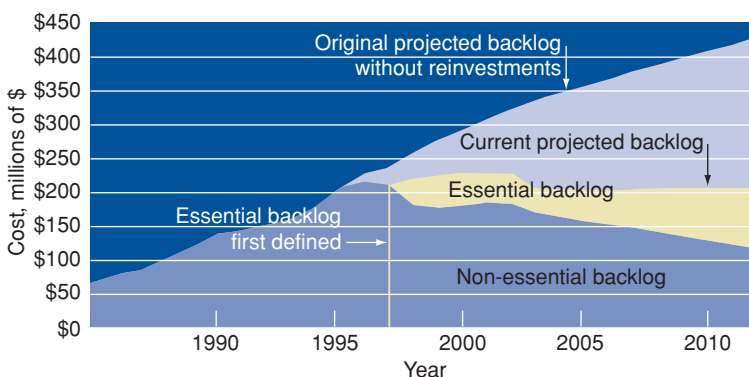


Figure 4-4a. Deferred maintenance growth without FIRP funding (in \$M).

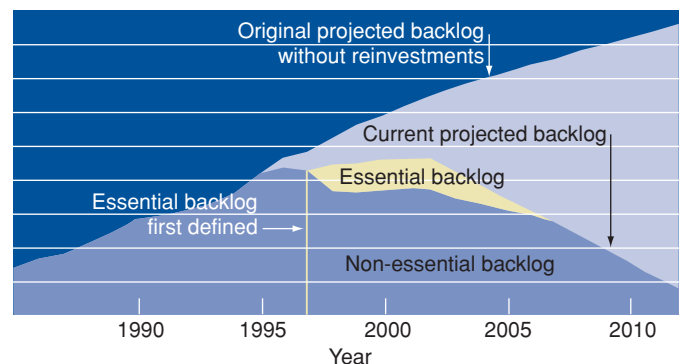


Figure 4-4b. Deferred maintenance growth with FIRP funding (in \$M).

computing systems in the world.

Energetic Materials Processing Center (EMPC) (FY 2004; TEC: \$44.0 M).

EMPC received approval for the Critical Decision 0 (CD-0), and conceptual design is in progress. EMPC will provide a capability for increased precision in 3D experiments for the national hydrodynamics program. EMPC, a vital component in the portfolio of Stockpile Stewardship Program facilities and capabilities, will provide the safe, repeatable, high-precision formulation and processing of high-explosive components used in the stockpile experimental program. In addition, the facility will replace 40-year-old facilities that are now

barely adequate to properly support the Stockpile Stewardship Program.

Tritium Facility Modernization (TFM) (FY 2004; TEC: \$9.4 M).

The TFM project received approval for the Critical Design 0 (CD-0), and conceptual design is in progress. The project will provide a hydrogen isotope research and development capability in Livermore's existing tritium facility (Building 331). This will enable Livermore programs to meet mission objectives in stockpile stewardship and energy research focused on behaviors, properties, and uses of hydrogen and its isotopes under a variety of extreme conditions including low to high pressures and cryogenic to high temperatures.

Isotope Science Facility (FY 2002; TEC: \$17.4 M).

Building 155, a two-story, 22,000-square-foot building, will contain 65 permanent offices and an auditorium for Chemistry and Materials Science directorate staff adjacent to Building 151, the Isotope Sciences Laboratory Facility.

In addition, FY 2002 funding is under way for FIRP. Activities include recapitalization projects, decontamination, demolition, and planning. Other funded projects include the central cafeteria replacement, maintenance reinvestment projects for replacing failed facility and infrastructure systems and components, and legacy and equipment cleanup.

Table 4-7. Funded and proposed major construction (in \$M).^a

Project title	TEC	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 BA	FY 2006 BA	FY 2007 BA	FY 2008 BA
Funded projects:									
National Ignition Facility	2,094.9	251.5	277.2	214.0	150.0	130.0	130.0	120.0	10.0
Terascale Simulation Facility	92.1	4.6	12.1	35.0	25.0	3.2			
Protection of Real Property—II	19.9	3.5	3.5	5.9	3.5				
Isotope Sciences Facility	17.4	2.0	6.4	4.0					
DAHRT (support) ^b	18.7	4.8	1.0						
Decontamination/Waste Treatment Facility ^c	62.4	4.3	2.1						
Sensitive Compartmented Information Facility (SCIF)	24.6	1.5	3.9	9.6					
Engineering Technology Complex Upgrade	26.7		1.3	10.0	9.8				
Total funded construction		280.2	307.5	278.5	188.3	133.2	130.0	120.0	10.0
Proposed projects:^e									
Tritium Facility Modernization	9.4				1.5		7.9		
Energetic Materials Processing Center	44.0				2.9	1.5	21.0	18.6	
High Explosives Development Center	50.0								5.0
Site Utilities Upgrade Project—FIRP	29.8				3.0		8.3	11.0	7.5
Building utilities—FIRP	29.0					3.0		9.0	10.0
Consolidated Security Facility ^c	25.0						2.0		8.7
Total new funding requirements					7.4	4.5	39.2	38.6	31.2
Total		280.2	307.5	278.5	195.7	137.7	169.2	158.6	41.3

^aBudget obligation (BO) FY 2001–2002; budget authorization (BA) FY 2003–2008.

^bSupport to a non-LLNL-managed line item; TEC is the sum of expected funding.

^cNNSA *Ten Year Comprehensive Site Plan* (May 2002) used for the information. Out-year funding for the Consolidated Security Facility High Explosives Development Center not included in Section 5 Resource Requirement tables.

^dTotal for FY 2001 includes \$8.0 million in funding for projects closed that year and not listed in table.

4.5 Business and Financial Support

Programmatic work at the Laboratory is supported by business, procurement, financial, and other types of services. Livermore is making considerable improvements in its operational support for programs, striving to size and manage support activities to optimize overall cost effectiveness and performance. As gauged by performance measures in the UC–DOE contract, Laboratory support functions are increasing in quality, delivered in a timely manner, and priced competitively.

We strive to provide operational services in a professional manner and to institute equitable procedures and systems that support Laboratory values. As a public-sector organization engaged primarily in contract work for DOE and other federal agencies, the Laboratory conforms to regulatory requirements—an important factor affecting the operations environment. Our support and service organizations provide assurance that compliance is managed responsibly and efficiently and in a way that is clearly defensible to the public, regulators, and Laboratory programs.

Situation and Issues

Reducing Support Costs. Many improvements have been made to reduce support and overhead costs, making more resources available for direct program work. The actions were taken with a view toward maintaining and improving institutional health and protecting the Laboratory's capability to conduct essential operations, such as in ES&H.

Functional elements that are responsible for providing many Laboratory-wide support services have undergone significant reengineering to improve efficiency, reduce costs, and better understand and meet customer needs and expectations. We have

adopted best commercial practices whenever possible and optimized business information systems to improve communications at all levels. This reengineering has benefited from major changes at DOE—use of an outcome-based oversight model for some aspects of operations, a shift to an aggressive self-assessment process, and implementation of meaningful metrics to assess performance. Rapid changes in technology also offer many opportunities for improvements in information systems (see Section 4.6).

Procurement and Materiel

Requirements. It is the policy of DOE to fully integrate small businesses, small disadvantaged businesses, women-owned businesses, Historically Underutilized Business Zone (HUBZone) businesses, and veteran-owned business concerns in DOE's core mission and programs. Accordingly, the Laboratory is required to provide opportunities to increase to the maximum extent practicable the participation of these firms in the acquisition process. (See Table 5-3 in Section 5.)

The Procurement and Materiel (P&M) Department is assigned annual goals by DOE in prescribed socioeconomic categories. In support of this requirement and working in concert with resource analysts from around the Laboratory, P&M uses a sophisticated forecasting model to develop a strategy to meet the assigned socioeconomic goals. The goals, carefully monitored and compared to actual procurements throughout the fiscal year, may be adjusted at midyear, depending on changes to individual program spending plans or the Laboratory budget at large.

Strategy Thrusts

The Laboratory will continuously improve systems and processes for providing support services, and we will also effectively communicate with and

involve both employees and customers in the change process.

Anticipating Customer Needs.

Successful reengineering includes anticipating customer expectations; soliciting continual customer feedback to assess satisfaction, needs, and strategies; and continuing aggressive use of industry and government benchmarking to enable effective comparisons and adopt best practices. Reengineering approaches will continue to take advantage of modern information technology and adopt off-the-shelf approaches whenever possible (see Section 4.6). In some cases, we will rely on institutional reinvestment to absorb short-term expenses that will lead to long-term cost savings. When outsourcing is a viable option, organizations are staffed to take advantage of it.

Balancing Priorities. In planning for and delivering operational support, the Laboratory strives to balance resource allocations so that programmatic work is performed responsibly, cost effectively, and in compliance with regulatory and other requirements. Implementation of this strategy also ensures that Laboratory policies permit local flexibility but not to the point at which local optimization undercuts compliance or other institutional objectives.

4.6 Business Systems and Information Technology

The Laboratory constantly seeks to upgrade business systems and practices. In particular, new information technologies offer the potential for vast improvements. Today, typical office professionals have access to more computing power than early supercomputers offered.

4.6.1 Business Systems

The Laboratory's business systems and information planning process

explores, compares, and learns about new business approaches and technologies that can be used to improve our business practices and information architecture. Our studies address crosscutting business issues in designing our future business systems architecture.

The themes for these planning processes include:

- Determining the crucial needs and directions for future Laboratory business systems.
- Identifying cross-organizational requirements for supporting external business partners.
- Determining best future practices that will achieve cost reductions, cycle-time reductions, and quality improvements and will allow end users to access self-service applications.
- Ensuring that explicit business systems align with Laboratory programs and projects.
- Understanding and influencing the strategic directions as determined by Livermore's information architecture activities sponsored by the chief information officer (CIO).
- Identifying and recommending for implementation the best-of-class strategies, business systems, applications, and technologies from industry and sister laboratories.

Situation and Issues

Business Systems Architecture. The business systems architecture must respond to changing business needs that require the use of evolving technologies. Managing and deploying an evolving business system and technical infrastructure have unique problems. In this type of environment, the complexity increases as the number of interrelated applications and users increases and as the time to technical maturity decreases. Our challenge is to provide an agile, responsive infrastructure with reliable, secure, and scalable production services.

Meeting this challenge requires fusion between the Livermore business and technology strategies, continual prudent evolution of technical capability, and a future infrastructure designed for serviceability to our business units.

Our business systems architecture is heavily influenced and validated by benchmarking and best-practice activities. In our benchmarking process, we study large, technically sophisticated organizations familiar with technologies that are a part of our current infrastructure and future directions. The organization can be a key technology vendor or other DOE national laboratory. During this process, we review information technology (IT) infrastructure, drivers of change, and future directions.

In the best-practices arena, the scope of the interactions is much more specific. First, we identify critical technology directions in which the solutions are unproven and relatively high-risk. We then find organizations that have experience and knowledge in the technical area and compare approaches and results. We also review our critical current technologies and processes to assess how we are doing.

In both cases, the objectives include:

- Identifying innovative approaches and technologies relevant to our future.
- Validating our major tactical and strategic directions, including feasibility, risks, costs, and benefits.
- Evaluating our strategic and tactical alignment with our vendors and the IT industry.
- Assessing our progress relative to similar organizations and industry as a whole.

During FY 2002 and beyond, we will investigate industry directions and implement major architectural changes, particularly in authentication, access control, intranet portals, workflow, integrated help-desk knowledge base, desktop and mobile computing management, and computer security.

Strategy Thrusts

Information Technology Professionals Recruitment and Retention.

We continue to face strong competition in the demand versus supply of IT skills critical to the Laboratory, a situation that we believe will continue through 2006. The shortage of critically skilled IT professionals, particularly given our proximity to Silicon Valley, has made it imperative to create a strategic thrust in building and maintaining tomorrow's workforce. To shape our future directions, we are conducting a major initiative to study the possibilities and implications of new management styles required for the next wave of new employees, sophisticated reward systems, alternative workforce sourcing arrangements, and various recruitment models, practices, and policies for selective retention. These multifaceted studies will help us redefine and deploy robust, rational, and strategic IT skills-management programs.

Enterprise-Scale Applications. The fundamental driver for our strategic planning is enabling cost and cycle-time reductions or quality improvements for key business processes. For example, a number of leading-edge organizations have realized significant cost and cycle-time reductions by moving processes out to end-point participants via the Web and automating everything in between. These applications are sometimes referred to as enterprise self-service applications, which we have adopted as our primary strategic direction.

We are replacing manual processes with enterprise-scale self-service applications (timecard, training, budgeting, purchasing) delivered to the browsers at the desktop. The Web technologies also enable us to extend business processes to external vendors and partners. Over the last three years, our user population has gone from about

1,500 users to approximately 7,000 with little increase in infrastructure staffing.

Intranet Portals and Web-Based Systems. Providing customized Web portals for specific customer segments is a major trend in industry. Many organizations have internal home pages that provide access to Websites, Web-based applications, and a common entry point for accessing the ever-increasing volume of Web content. In the first phase of a similar effort, we are implementing ways to provide a user-customizable intranet Web portal that integrates internal and external Website access, Web-based application access, workflow in-basket, messaging, and utilities integrated with single sign-on and integrated access control.

A second phase for this effort will be creating portals for specific customer segments, including workbenches for resource managers, enterprise users, project managers, and human resource managers.

Electronic Commerce Initiatives. The Internet is driving an emerging revolutionary business paradigm at Livermore. Virtual relationships and collaborations between Laboratory business units and external partners are emerging at an ever-increasing rate. We currently provide electronic data interchange based on just-in-time purchasing capabilities with a virtual catalog of over 1.5 million items. In the near term, we are expanding our use of collaborative technologies that support engineering designs and job orders, and we are moving forward with the application of commercial business-to-business purchasing networks.

4.6.2 Information Technology

IT spans many projects, services, and operations that involve the acquisition, development, maintenance, and

management of hardware, software, applications, information management systems, and networks. The productivity of typical office professionals—technical, scientific, or administrative—depends on the connectivity and secure use of all IT resources as well as the information that is saved or shared.

Situation and Issues

A New Chief Information Officer. This year, the Laboratory's chief information officer (CIO) function has been broadened, and a new CIO has been hired, providing vision and leadership to deal with the growing complexity and use of IT throughout all Laboratory operations and programs. The CIO is focusing on:

- Maximizing common IT solutions whenever possible to achieve economy of scale and uniformity of purpose.
- Providing IT solutions that both improve efficiency and provide best-in-class capabilities for our programs.
- Interacting outside the Laboratory with DOE, NNSA, and the Office of Management and Budget regarding regulatory issues in security, information architecture, and electronic-Government initiatives.

Strategy Thrust

Strategic Planning for Information Technology.

The CIO's strategic planning approach will include an assessment of our current state, definition of future state, and a roadmap to get there. The plan will include a vision for "horizontal" infrastructure such as network architecture, communication, servers, platforms, and desktops and a vision for "vertical" infrastructure to integrate enterprise data to support business and planning functions as well as scientific and experimental data. These visions should

be consistent and compatible with a long-term security and authentication architecture.

Managing IT resources in this focused fashion will reduce redundancy and create a more uniform and modern IT environment for all of the Laboratory's diverse programs. In addition, our financial models for IT investments will also become more uniform. The CIO will work closely with the chief financial officer (CFO) to achieve consistent funding and cost recovery models for our diverse common benefit projects and to provide processes for review and prioritization of IT investments from a technological perspective.

We are aware that as the IT content of new science grows, programs will continue to invest in program-specific IT solutions. The CIO will work with major programs and the directorates to build this common vision for infrastructure, enterprise data applications, and architecture. Through a common strategic IT vision, program investments and common Laboratory-wide investments can be leveraged to create more effective use of all IT resources.

4.7 Internal and External Communications

The Laboratory is a national resource center of applied science and technology. In this role, we serve diverse customers and strive to meet the needs of many stakeholders. These interactions range from the broad scientific community and the leaders of the federal government to our own local community and Livermore employees.

The Public Affairs Office (PAO) serves as a principal conduit of the Laboratory's internal and external communications program for bringing

the Laboratory's messages to important audiences and seeking the concerns and comments of those audiences. Internally, the Laboratory needs effective management-to-employee communication to support dialogue on key issues, institutional decision making, and dissemination of institutional information. Externally, the Laboratory is striving to be seen locally, nationally, and internationally as a credible and authoritative source on issues relevant to our mission. We want to be perceived as an intellectual asset to the state of California and a helpful neighbor in the Bay Area and California's Central Valley, and we want the communities around us to be proud we are here.

Situation and Issues

Listening to Our Customers.

The Laboratory must continue to ensure that customers and stakeholders are identified and that their concerns are considered in planning and decision making as well as in the formulation of operational policies. The range of customers and stakeholders is extremely wide, from the general public to senior managers in Washington, D.C.

Improving Community Relations. The Laboratory continues to reach out to stakeholders and customers, participate in community events, and seek feedback directly from the public. We are aware that relations with the community are fundamentally sound, but most members of the community would like more information about our activities. As a result, PAO recently strengthened its community relations staff, began a monthly electronic community newsletter, and began a public lecture series. On topics of key interest to the general public—such as the pending controlled access of East Avenue or security in a post–September 11 world—

the Laboratory held a number of neighborhood meetings, allowing local citizens to gain a better understanding of the Laboratory and its intended actions. The Visitors Center—one of the few “open” areas on site—has undergone major remodeling and changed its name to the Discovery Center, and new community tours have been added. On a regular basis, select groups have enjoyed special tours of NIF, Forensic Science Center, and biological facilities. In 2001, the Laboratory also began a series of special Saturday events at the Discovery Center, offering the general public a glimpse into the Laboratory's world. Our 50th anniversary celebration is also generating greater community exposure at key public events. A special Laboratory float—built by and outfitted with employees—appeared at four local community parades in 2002.

The Laboratory also hosted a Science Day on March 21, 2001, which showcased our supercomputer-assisted research as well as other crowning achievements in science and technology. The community and all employees were invited, and opening comments were provided by the Laboratory director, NNSA Administrator John Gordon, and UC Provost and Senior Vice President C. Judson King.

In addition, as a Superfund site, Livermore participates in a national program on health assessment conducted by the Agency for Toxic Substances and Disease Registry. We participate in community meetings on public health issues about Laboratory environmental restoration activities and operations. We publish a newsletter and offer a Website on these topics, and we frequently respond to questions from students, members of the general public, home buyers, and realtors. We also interact regularly with city leaders on potential

health and community environmental issues to ensure that our laboratory position and action plans are well known.

Among the many other interactions the Laboratory has with the local community is our effort to establish consolidated fire dispatch within the County of Alameda. In March 2002, after more than five years of study, the Laboratory, Alameda County Fire Department, Alameda County Emergency Services Agency, and Alameda City Fire Department agreed to form a consortium to consolidate emergency dispatch services. Consolidation saves participants money, improves fire and emergency medical services, and improves mutual aid. Other organizations could be attracted to join after they see the advantages of the system. The new Consolidated Emergency Dispatch Center is located at the Laboratory.

We are also working closely with area mutual aid agencies and the cities in the Tri-Valley area on the subject of coordinated emergency planning information. We want to ensure that the general public receives all information needed to make effective personal decisions during any type of emergency that could occur in the area.

Strategic Thrusts

Information Outlets. The Laboratory is using advances in technology to improve internal communications and external communication with the general public, local and regional audiences, and leaders in the federal government. We are extensively using the Internet for all of these audiences. For example, the Laboratory newspaper, *Newsline*, has an online version (*NewsOnLine*) that is issued to employees twice weekly. Selected *Newsline* articles are posted on the publicly accessible PAO Website.

Similarly, Public Affairs news releases and photos are posted on the Web. *Newsline* and *My LLNL* (our internal Web portal) carry a “From the Director” column, which provides employees with information about key institutional efforts and Laboratory issues. In addition, the Laboratory, in conjunction with local cable TV, has a weekly talk show, “Technology Today,” which reaches the local public with nontechnical discussions of ongoing projects.

Online Communications. Institutional publications, such as *Creating the Laboratory’s Future*, *Science &*

Technology Review, *Laboratory Annual Report*, news releases, and major stories from *Newsline* are available on the Laboratory’s external Website. More generally, Livermore’s external Website is a national resource of science and technology information. Many publications are available online, and information is provided about our organization, operations, and programs as well as opportunities for employment and research partnerships.

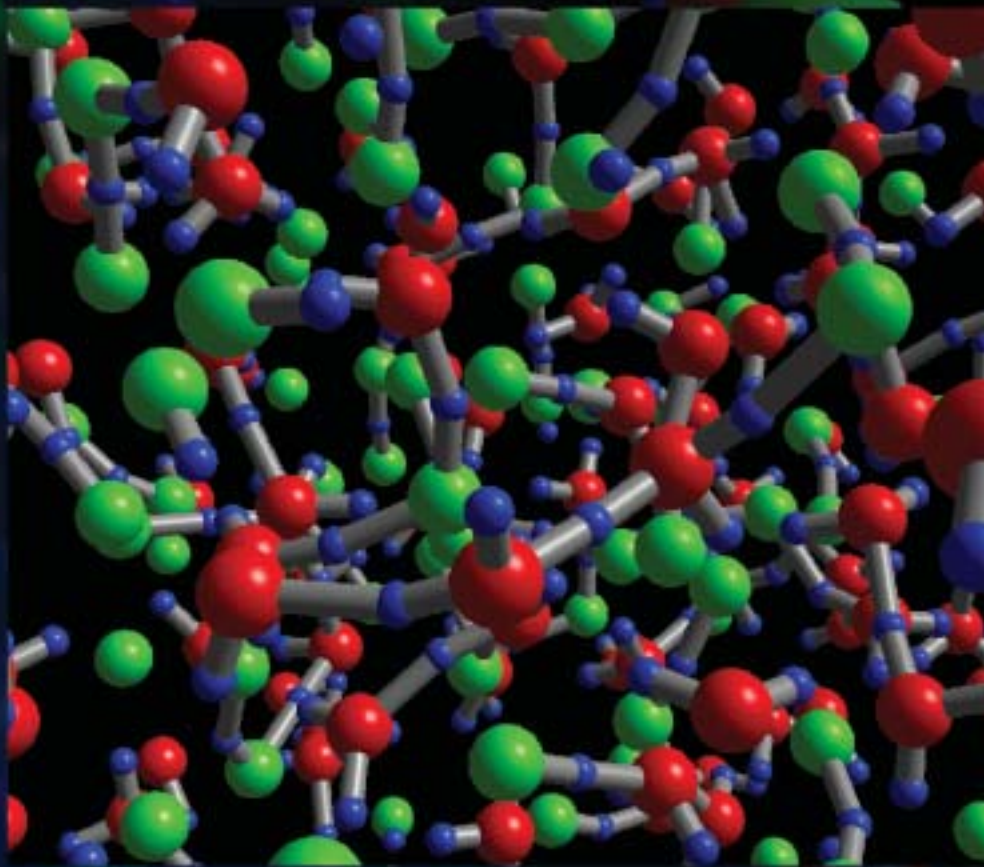
Web pages for general public use, such as PAO’s, recently have been redesigned for greater clarity and improved public

access and usefulness. The Laboratory’s internal Website, *The Grapevine*, has been completely revamped this year into *MyLLNL*, an “enterprise portal,” which allows individual users to customize its functions. Internal Websites provide employees with organizational information, policies and procedures, institutional databases, online training and testing, standard forms, business information, event calendars, and electronic newsletters. DOE has cited many of our administrative and operations Websites for using “best practices.”

SECTION 5

Institutional Plan FY 2003–2008

Appendices



First-principles molecular dynamics simulation of changes in a mixture of hydrogen fluoride and water under pressure. This quantum simulation was carried out using the Livermore-developed GP code. The code reveals dissociation effects that are analogous to the behavior of high-explosives mixtures under pressures close to detonation conditions and important changes of hydrogen bonding under pressure.

5.1 Program Resource Requirement Projections

Data for FY 2001 and FY 2002 are actual cost outlays, or budget obligations (BO). For FY 2003 and the out years, the figures are projections of budget authority (BA). For the NNSA Defense Programs projections, the data come from the NNSA Future Years National Security Plan (FYNSP). Other DOE offices provide BA estimates for FY 2003 through FY 2005, and level funding is assumed for subsequent years (no inflation factor included). Non-DOE Work-for-Others estimates are provided for FY 2003 and FY 2004, and thereafter funding is extrapolated to be level (no inflation factor included).

The program resource projections are presented in the following tables:

- Tables 5.1-1 and 5.1-2. Laboratory funding and personnel summaries.
- Tables 5.1-3. Resources (operating and maintenance and construction) by major DOE program.
- Tables 5.1-4 through 5.1-24. Detailed resource breakouts by DOE NNSA and Assistant Secretary offices.
- For the future years (the BA projections), data are provided for operating and

maintenance and for construction.

Operating and maintenance includes funding that will be used for general plant projects and for capital equipment. To illustrate trends in these expenditures, Table 5.2-1 shows capital equipment BO for FY 2001 and FY 2002 by DOE funding source. Table 5.2-2 shows similar data for general plant projects.

- Table 5.3. Data concerning small and disadvantaged business procurement.

The formulation of other (non-DP) NNSA program budgets was completed as part of NNSA's Planning, Programming, Budgeting, and Evaluation process. The data were developed at DOE Headquarters. BA for these programs was estimated by Livermore resource analysts for the purpose of out-year planning only. BA was estimated through FY 2004 for Safeguards and Security and through FY 2005 for Defense Nuclear Nonproliferation. Level funding (no inflation factor included) was assumed for subsequent years.

Other DOE offices provided programmatic and financial guidance. FY 2003 and FY 2004 BA estimates and FTEs were developed based on that information. Level funding was assumed for subsequent years.

Table 5.1-1. Laboratory funding summary (in millions of dollars, \$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
DOE Operating & Maintenance Programs ²	876.3	970.3	960.7	1,082.6	1,135.5	1,170.2	1,190.9	1,174.7
Work-for-Others DOE Facilities & Field Offices	85.7	119.0	83.5	72.3	72.3	72.3	72.3	72.3
Work-for-Others Non-DOE	131.0	143.3	185.7	170.6	170.6	170.6	170.6	170.6
Total Operating	1,093.0	1,232.6	1,229.8	1,325.5	1,378.4	1,413.1	1,433.9	1,417.6
DOE Program Construction	280.2	307.5	278.6	195.7	137.7	167.2	158.6	30.1
Total	1,373.3	1,540.1	1,508.4	1,521.2	1,516.1	1,580.3	1,592.5	1,447.7

¹As part of the Future Years National Security Plan (FYNSP), NNSA/Defense Programs provided out-year planning numbers. For other DOE Assistant Secretaries/Offices, FY 2004/2005 estimates were carried forward as out-year projections.

²Includes capital equipment and general plant projects.

Table 5.1-2. Laboratory personnel summary (in full-time employee equivalent, or FTE).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 BA	FY 2006 BA	FY 2007 BA	FY 2008 BA
Direct								
DOE Direct/Direct Support	4,667	4,898	5,070	5,070	5,070	5,070	5,070	5,070
Work-for-Others DOE Facilities & Field Offices	401	430	450	450	450	450	450	450
Work-for-Others Non-DOE	601	622	625	625	625	625	625	625
Total Direct	5,669	5,950	6,145	6,145	6,145	6,145	6,145	6,145
Total Indirect	1,422	1,507	1,555	1,555	1,555	1,555	1,555	1,555
Total Personnel	7,091	7,457	7,700	7,700	7,700	7,700	7,700	7,700

Table 5.1-3. Funding by Secretarial Office (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
NNSA–Defense Programs								
Operating & Maintenance	562.4	630.2	581.4	684.4	744.6	779.3	800.4	784.1
Construction	274.2	304.8	278.6	195.7	137.7	167.2	158.6	30.1
NNSA–Defense Nuclear Nonproliferation								
Operating & Maintenance	100.8	117.6	103.0	100.0	92.3	92.3	92.3	92.3
NNSA–Safeguards & Security								
Operating & Maintenance	62.7	78.7	93.0	98.0	98.0	98.0	98.0	98.0
NNSA–Naval Reactors								
Operating & Maintenance ²	0.3	0.3	–	–	–	–	–	–
Science								
Operating & Maintenance	54.4	53.5	68.4	67.2	67.2	67.2	67.2	67.2
Environmental Management								
Operating & Maintenance	45.7	42.0	68.3	85.1	85.1	85.1	85.1	85.1
Construction	4.3	2.1	0.0	0.0	0.0	0.0	0.0	0.0
Security & Emergency Operations								
Operating & Maintenance	21.2	6.0	12.8	12.4	12.4	12.4	12.4	12.4
Management, Budget, & Evaluation								
Operating & Maintenance ²	9.0	12.2	–	–	–	–	–	–
Energy Efficiency & Renewable Energy								
Operating & Maintenance	6.3	6.3	7.8	8.6	8.6	8.6	8.6	8.6
Construction	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Intelligence								
Operating & Maintenance	3.8	4.4	5.4	5.7	5.7	5.7	5.7	5.7
Construction	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Counterintelligence								
Operating & Maintenance	3.5	3.8	4.3	5.4	5.4	5.4	5.4	5.4
Environment, Safety, & Health								
Operating & Maintenance	2.8	2.8	2.9	2.8	2.8	2.8	2.8	2.8
Fossil Energy								
Operating & Maintenance	2.7	3.0	3.3	3.4	3.7	3.7	3.4	3.4
Nuclear Energy, Science, & Technology								
Operating & Maintenance	0.5	1.2	2.5	1.9	1.9	1.9	1.9	1.9
Civilian Radioactive Waste Management								
Operating & Maintenance	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2

Table 5.1-3, continued. Funding by Secretarial Office (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Energy Awareness Operating & Maintenance ²	0.0	0.1	–	–	–	–	–	–
Chief Information Officer Operating & Maintenance	0.0	8.1	7.3	7.5	7.5	7.5	7.5	7.5
Independent Oversight & Performance Assurance Operating & Maintenance ³	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Policy Operating & Maintenance ²	0.0	0.0	–	–	–	–	–	–
Total DOE Programs Operating & Maintenance	876.3	970.3	960.7	1,082.6	1,135.5	1,170.2	1,190.9	1,174.7
Construction	280.2	307.5	278.6	195.7	137.7	167.2	158.6	30.1
Work-for-Others DOE Facilities & Field Offices Operating & Maintenance	85.7	119.0	83.5	72.3	72.3	72.3	72.3	72.3
Work-for-Others Non-DOE Operating & Maintenance	131.0	143.3	185.7	170.6	170.6	170.6	170.6	170.6
Total Work-for-Others Funding Operating & Maintenance	1,093.0	1,232.6	1,229.8	1,325.5	1,378.4	1,413.1	1,433.9	1,417.6
Construction	280.2	307.5	278.6	195.7	137.7	167.2	158.6	30.1
Total	1,373.3	1,540.1	1,508.4	1,521.2	1,516.1	1,580.3	1,592.5	1,447.7

¹As part of the Future Years National Security Plan (FYNSP), Defense Programs provided out-year planning numbers. For other DOE Assistant Secretaries/Offices, FY 2004/2005 estimates were carried forward as out-year projections.

²No funding projections were available for this Budget & Reporting (B&R) code.

³FY 2002 actuals and FY 2003/2004 projections were less than \$50,000.

Table 5.1-4. National Nuclear Security Administration—Defense Programs (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Cerro Grande Fire Activities (DARHT)–CG²								
Construction	1.4	0.0	–	–	–	–	–	–
Directed Stockpile Work–DP07								
Operating & Maintenance	59.8	83.2	99.4	103.5	105.2	108.6	110.6	115.3
Campaigns–DP08								
Operating & Maintenance	336.6	349.5	280.0	314.3	332.6	342.0	360.9	325.0
Construction	8.0	13.1	35.0	25.0	3.2	0.0	0.0	0.0
Inertial Confinement Fusion (ICF) Ignition & High Yield–DP0810								
Operating & Maintenance	114.8	129.8	118.9	176.0	207.5	226.7	230.6	240.2
Construction	251.5	277.2	214.0	150.0	130.0	130.0	120.0	10.1
Readiness in Technical Base & Facilities (RTBF)/ NEST/ARAC–DP09								
Operating & Maintenance	50.1	58.3	56.4	56.7	58.0	59.5	61.0	61.6
Construction	13.3	14.6	29.5	17.7	1.5	28.9	18.6	0.0
NNSA Facilities & Infrastructure (F&I)–DP10								
Operating & Maintenance	0.3	8.1	26.8	33.8	41.2	42.4	37.2	42.0
Construction	0.0	0.0	0.0	3.0	3.0	8.3	20.0	20.0
Program Direction–PS								
Operating & Maintenance	0.8	1.2	0.0	0.0	0.0	0.0	0.0	0.0
Total Defense Programs								
Operating & Maintenance	562.4	630.2	581.4	684.4	744.6	779.3	800.4	784.1
Construction	274.2	304.8	278.6	195.7	137.7	167.2	158.6	30.1

¹As part of the Future Years National Security Plan (FYNSP), NNSA/Defense Programs provided out-year planning numbers. For other DOE Assistant Secretaries/Offices, FY 2004/2005 estimates were carried forward as out-year projections.

²No funding projections were available for this Budget & Reporting (B&R) code.

Table 5.1-5. National Nuclear Security Administration—Nonproliferation and National Security Program (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Defense Nuclear Nonproliferation–NN Operating & Maintenance	100.8	117.6	103.0	100.0	92.3	92.3	92.3	92.3

¹FY 2005 estimates were carried forward as projections for FY 2006–FY 2008.

Table 5.1-6. National Nuclear Security Administration—Safeguards and Security Program (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Safeguards & Security–FS Operating & Maintenance	62.7	78.7	93.0	98.0	98.0	98.0	98.0	98.0

¹FY 2004 estimates were carried forward as projections for FY 2005–FY 2008.

Table 5.1-7. National Nuclear Security Administration—Naval Reactors (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 ¹ BA	FY 2004 ¹ BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Naval Reactors Development–AJ Operating & Maintenance	0.3	0.3	–	–	–	–	–	–

¹No funding projections were available for this Budget & Reporting (B&R) code.

Table 5.1-8. Science (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Fusion Energy Sciences–AT								
Operating & Maintenance	14.7	14.6	15.2	15.9	15.9	15.9	15.9	15.9
Program Direction—Safeguards & Security–FS15²								
Operating & Maintenance	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
High Energy Physics–KA								
Operating & Maintenance	1.1	1.3	1.5	2.3	2.3	2.3	2.3	2.3
Nuclear Physics–KB								
Operating & Maintenance	0.7	0.6	0.9	1.0	1.0	1.0	1.0	1.0
Basic Energy Science–KC								
Operating & Maintenance	5.4	5.4	6.3	6.5	6.5	6.5	6.5	6.5
Facilities & Infrastructure–KH								
Operating & Maintenance	0.0	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Computational & Technology Research–KJ								
Operating & Maintenance	3.4	6.5	6.0	6.1	6.1	6.1	6.1	6.1
Biological & Environmental Research–KP								
Operating & Maintenance	28.9	24.6	38.2	35.1	35.1	35.1	35.1	35.1
Program Direction–KX²								
Operating & Maintenance	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total Science								
Operating & Maintenance	54.4	53.5	68.4	67.2	67.2	67.2	67.2	67.2

¹FY 2004 estimates were carried forward as projections for FY 2005–FY 2008.²FY 2002 actuals and FY 2003/2004 projections were less than \$50,000.

Table 5.1-9. Environmental Management (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Defense ER & WM–EW								
Operating & Maintenance	43.9	41.3	66.6	83.4	83.4	83.4	83.4	83.4
Construction	4.3	2.1	0.0	0.0	0.0	0.0	0.0	0.0
Non-Defense Environmental Management–EX								
Operating & Maintenance	1.8	0.7	1.7	1.7	1.7	1.7	1.7	1.7
Total Environmental Management								
Operating & Maintenance	45.7	42.0	68.3	85.1	85.1	85.1	85.1	85.1
Construction	4.3	2.1	0.0	0.0	0.0	0.0	0.0	0.0

¹FY 2004 estimates were carried forward as projections for FY 2005–FY 2008.

Table 5.1-10. Security and Operations (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Nuclear Safeguards & Security–GD								
Operating & Maintenance	13.3	6.0	12.8	12.4	12.4	12.4	12.4	12.4
Emergency Management–ND								
Operating & Maintenance ²	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Security & Emergency Operations–SO								
Operating & Maintenance ²	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Security & Emergency Operations								
Operating & Maintenance	21.2	6.0	12.8	12.4	12.4	12.4	12.4	12.4

¹FY 2004 estimates were carried forward as projections for FY 2005–FY 2008.

²FY 2002 actuals and FY 2003/2004 projections were less than \$50,000.

Table 5.1-11. Management, Budget, and Evaluation (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 ¹ BA	FY 2004 ¹ BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Costs Associated with Safeguards & Security Attributed to WFO–WN Operating & Maintenance	9.0	12.2	–	–	–	–	–	–

¹No funding projections were available for this Budget & Reporting (B&R) code.

Table 5.1-12. Energy Efficiency and Renewable Energy (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Solar & Renewable Resource Technologies–EB Operating & Maintenance	3.1	3.1	3.6	4.3	4.3	4.3	4.3	4.3
Industry Sector–ED Operating & Maintenance ²	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Transportation Sector–EE Operating & Maintenance	2.9	2.7	4.0	4.1	4.1	4.1	4.1	4.1
Federal Energy Management Program–EL Operating & Maintenance ²	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
In-House Energy Management–WB Operating & Maintenance	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Construction ²	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Energy Efficiency & Renewable Energy Operating & Maintenance	6.3	6.3	7.8	8.6	8.6	8.6	8.6	8.6
Construction ²	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0

¹FY 2004 estimates were carried forward as projections for FY 2005–FY 2008.

²FY 2002 actuals and FY 2003/2004 projections were less than \$50,000.

Table 5.1-13. Intelligence (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Intelligence–IN								
Operating & Maintenance	3.8	4.4	5.4	5.7	5.7	5.7	5.7	5.7
Construction ²	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0

¹FY 2004 estimates were carried forward as projections for FY 2005–FY 2008.
²Projections were less than \$50,000.

Table 5.1-14. Counterintelligence (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Counterintelligence–CN								
Operating & Maintenance	3.5	3.8	4.3	5.4	5.4	5.4	5.4	5.4

¹FY 2004 estimates were carried forward as projections for FY 2005–FY 2008.

Table 5.1-15. Environment, Safety, and Health (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Environment, Safety, & Health–Non-Defense–HC								
Operating & Maintenance	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Environment, Safety, & Health–Defense–HD								
Operating & Maintenance	2.6	2.6	2.7	2.7	2.7	2.7	2.7	2.7
Total Environment, Safety, & Health								
Operating & Maintenance	2.8	2.8	2.9	2.8	2.8	2.8	2.8	2.8

¹FY 2004 estimates were carried forward as projections for FY 2005–FY 2008.

Table 5.1-16. Fossil Energy (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Coal & Power Systems– AA Operating & Maintenance	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Gas–AB Operating & Maintenance	0.4	0.6	0.6	0.3	0.6	0.6	0.3	0.3
Petroleum–AC Operating & Maintenance	1.0	1.3	1.6	2.0	2.0	2.0	2.0	2.0
Advanced Metallurgical Processes–AE Operating & Maintenance ²	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Fossil Energy Operating & Maintenance	2.7	3.0	3.3	3.4	3.7	3.7	3.4	3.4

¹FY 2004 estimates were carried forward as projections for FY 2005–FY 2008.²FY 2002 actuals and FY 2003/2004 projections were less than \$50,000.**Table 5.1-17. Nuclear Energy, Science and Technology (\$M).**

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Nuclear Research & Development–AF Operating & Maintenance	0.5	1.2	2.5	1.9	1.9	1.9	1.9	1.9

¹FY 2004 estimates were carried forward as projections for FY 2005–FY 2008.**Table 5.1-18. Civilian Radioactive Waste Management (\$M).**

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Waste Management System–DF Operating & Maintenance	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2

¹FY 2004 estimates were carried forward as projections for FY 2005–FY 2008.

Table 5.1-19. Energy Awareness (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 ¹ BA	FY 2004 ¹ BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Energy Security & Assurance–ES Operating & Maintenance	0.0	0.1	–	–	–	–	–	–

¹No funding projections were available for this Budget & Reporting (B&R) code.

Table 5.1-20. Chief Information Officer (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Computer Security Program–CS Operating & Maintenance	0.0	8.1	7.3	7.5	7.5	7.5	7.5	7.5

¹FY 2004 estimates were carried forward as projections for FY 2005–FY 2008.

Table 5.1-21. Independent Oversight and Performance Assurance (\$M).

	FY 2001 ¹ BO	FY 2002 ¹ BO	FY 2003 ¹ BA	FY 2004 ¹ BA	FY 2005 ^{1,2} BA	FY 2006 ^{1,2} BA	FY 2007 ^{1,2} BA	FY 2008 ^{1,2} BA
Independent Oversight & Assurance– Defense–PB Operating & Maintenance	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

¹FY 2001 and 2002 actuals and FY 2003/2004 projections were less than \$50,000.

²FY 2004 estimates were carried forward as projections for FY 2005–FY 2008.

Table 5.1-22. Policy (\$M).

	FY 2001 ¹ BO	FY 2002 ¹ BO	FY 2003 ^{1,2} BA	FY 2004 ^{1,2} BA	FY 2005 ^{1,2} BA	FY 2006 ^{1,2} BA	FY 2007 ^{1,2} BA	FY 2008 ^{1,2} BA
Policy Analysis and System Studies–PE Operating & Maintenance	0.0	0.0	–	–	–	–	–	–

¹FY 2001 and 2002 actuals were less than \$50,000.²No funding projections were available for this Budget & Reporting (B&R) code.**Table 5.1-23. Work-for-Others at DOE Facilities and Field Offices (\$M).**

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Work-for-Others—DOE Integrated Contractors Operating & Maintenance	28.6	38.7	30.7	22.1	22.1	22.1	22.1	22.1
Work-for-Others—DOE Installations Operating & Maintenance	57.1	80.3	52.8	50.2	50.2	50.2	50.2	50.2
Total WFO DOE Facilities & Field Offices Operating & Maintenance	85.7	119.0	83.5	72.3	72.3	72.3	72.3	72.3

¹FY 2004 estimates were carried forward as projections for FY 2005–FY 2008.

Table 5.1-24. Work-for-Others, Non-DOE (\$M).

	FY 2001 BO	FY 2002 BO	FY 2003 BA	FY 2004 BA	FY 2005 ¹ BA	FY 2006 ¹ BA	FY 2007 ¹ BA	FY 2008 ¹ BA
Department of Defense (DoD)								
Air Force	6.0	7.7	1.2	0.6	0.6	0.6	0.6	0.6
Army	18.2	17.9	13.1	18.1	18.1	18.1	18.1	18.1
Navy	7.2	10.8	11.6	1.3	1.3	1.3	1.3	1.3
Office of the Secretary of Defense (OSD)	5.0	6.0	8.0	8.0	8.0	8.0	8.0	8.0
BMDO ²	1.8	1.2	—	—	—	—	—	—
DTRA	12.4	14.1	8.3	3.5	3.5	3.5	3.5	3.5
DARPA	5.4	12.4	11.3	9.9	9.9	9.9	9.9	9.9
Other DoD	2.3	0.7	2.3	2.0	2.0	2.0	2.0	2.0
SERDP ²	0.1	—	—	—	—	—	—	—
OFA—Defense Related	16.7	21.9	78.3	82.5	82.5	82.5	82.5	82.5
Total Department of Defense	75.1	92.7	134.1	125.9	125.9	125.9	125.9	125.9
Non-DoD Federal								
NRC	0.9	1.1	1.4	1.4	1.4	1.4	1.4	1.4
NIH	6.6	6.4	11.0	11.0	11.0	11.0	11.0	11.0
NASA	2.1	3.3	1.9	1.9	1.9	1.9	1.9	1.9
DOI	0.2	0.5	0.3	0.3	0.3	0.3	0.3	0.3
DOS ²	0.5	3.7	—	—	—	—	—	—
DOT	1.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4
OFA—Energy Related	2.6	0.2	2.9	2.9	2.9	2.9	2.9	2.9
Total Non-DoD Federal	14.6	15.6	17.9	17.9	17.9	17.9	17.9	17.9
Other Federal Non-Contract²	1.4	—	—	—	—	—	—	—
Total Reimbursable WFO Federal Agencies	91.1	108.3	152.0	143.8	143.8	143.8	143.8	143.8
Non-Federal Work-for-Others	39.9	35.0	33.7	26.8	26.8	26.8	26.8	26.8
Total Non-DOE Work-for-Others	131.0	143.3	185.7	170.6	170.6	170.6	170.6	170.6

¹FY 2004 estimates were carried forward as projections for FY 2005–FY 2008.

²Estimates were not included in the Field Budget Submissions.

Table 5.2-1. Capital Equipment (\$M).

	FY 2001	FY 2002
AT–Fusion Energy Sciences	0.1	–
CS–Computer Security	–	0.6
DP07–Directed Stockpile Work (DSW)	0.5	0.3
DP08–Campaigns	11.0	14.6
DP09–Readiness in Technical Base & Facilities (RTBF)	0.4	0.5
DP10–Facilities & Infrastructure	–	0.1
EB–Solar & Renewable Resource Technologies	–	0.0
EW–Environmental Restoration & Waste Management (ERWM)	–	0.1
FS–Field Security	0.5	2.4
GD–Nuclear Safeguards & Security	0.1	0.2
KC–Basic Energy Sciences	0.5	0.4
KJ–Computational & Technology Research	–	0.0
KP–Biological & Environmental Research	0.3	0.3
NN–Defense Nuclear Nonproliferation	0.3	4.6
SO–Security & Emergency Operations	0.3	–
Total Capital Equipment	14.0	24.3

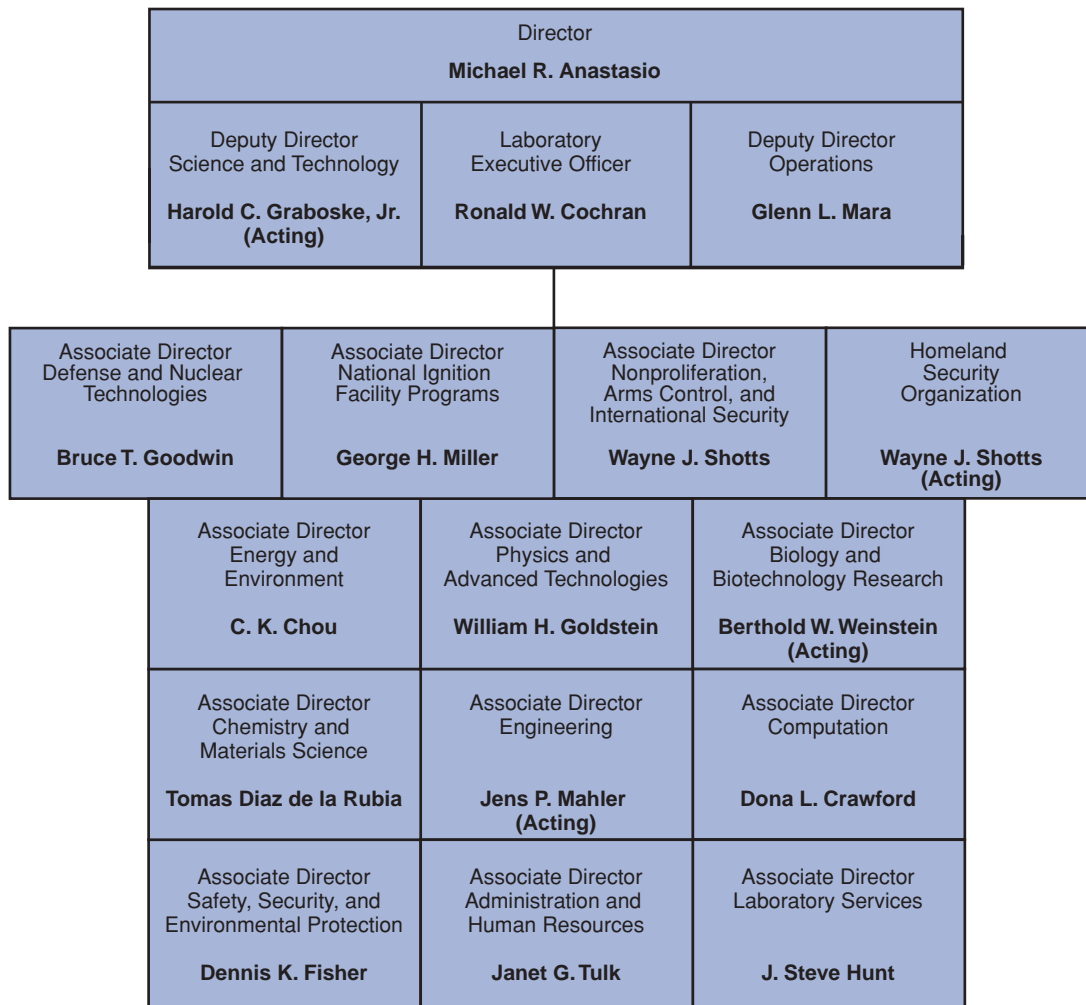
Table 5.2-2. General Plant Projects (\$M).

	FY 2001	FY 2002
DP07–Directed Stockpile Work (DSW)	1.1	1.3
DP08–Campaigns	0.5	1.5
DP09–Readiness in Technical Base & Facilities (RTBF)	0.2	0.7
DP10–Facilities & Infrastructure	–	1.9
EW–Environmental Restoration & Waste Management. (ERWM)	0.0	–
FS–Field Security	0.0	0.4
Total General Plant Projects	1.9	5.9

Table 5.3. Small and Disadvantaged Business Procurement (\$M).

Procurement Category	FY 1999	FY 2000	FY 2001	FY 2002
Procurement from Small and Disadvantaged Businesses	45.0	184.1	168.9	182.1
Percentage of Annual Procurement	15.9%	39.1%	39.9%	36.5%

5.2 Organization chart



5.3 Publications and Internet Addresses

General information about the Laboratory's work may be found electronically on the World Wide Web through the Laboratory's home page at <http://www.llnl.gov/>. Other references called out in this Institutional Plan are shown below.

Please direct requests for hard copies of Livermore publications to:

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Referenced Publications

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